International Journal of Community Medicine and Public Health
Fahad MS et al. Int J Community Med Public Health. 2026 Aug;13(8):4140-4148
https://www.ijcmph.com
pISSN 2394-6032 | eISSN 2394-6040

DOI: https://dx.doi.org/10.18203/2394-6040.ijcmph20262688

Original Research Article

Spatiotemporal dynamics, hotspot identification and surveillance performance of rubella in Nigeria

Muhammad Shehu Fahad[1,2]*, Alhaji A. Aliyu[3], Andrew N. Reigns[4], Darlington Chukwuma Ugwu[5], Oyeladun Okunromade[2]

[1]Department School of Public Health, University of Port Harcourt, Port Harcourt, Nigeria
[2]Nigeria Centre for Disease Control and Prevention (NCDC), Abuja, Nigeria
[3]Department of Community Medicine, Ahmadu Bello University, Zaria, Nigeria
[4]Department of Geography, Federal Polytechnic Ugep, Cross River State, Nigeria
[5]Africa Leadership in Vaccine Expertise (ALIVE), University of the Witwatersrand, Johannesburg, South Africa

Received: 03 June 2026
Accepted: 18 July 2026

***Correspondence:**
Dr. Muhammad Shehu Fahad,
E-mail: drfahd.muhammad@gmail.com

ABSTRACT

Background: Rubella remains endemic in Nigeria due to the absence of nationwide integration of rubella-containing vaccine (RCV) into routine immunization. Understanding spatial clustering, seasonal trends, and surveillance performance is critical for informing vaccination policy and outbreak preparedness.
Methods: A retrospective observational study was conducted using national rubella surveillance data (2020–2024). Laboratory-confirmed IgM-positive cases were analyzed using geospatial and time-series methods. Spatial clustering was assessed with Moran's I and Getis-Ord Gi statistics. Seasonal patterns were examined using seasonal-trend decomposition via loess (STL), and forecasting was performed with autoregressive integrated moving average (ARIMA) models. Surveillance performance was assessed using WHO timeliness indicators.
Results: Among 7,907 suspected cases, 4,001 (50.6%) were IgM-positive. The South East zone recorded the greatest burden (21.2%), with Ebonyi State identified as a significant hotspot (Gi=2.32, p=0.020). Moran's I (0.143; p=0.054) indicated weak spatial autocorrelation. Rubella incidence peaked consistently in May, with 2022 recording the highest annual total (1,065 cases; 26.6%). ARIMA forecasting projected 176 cases for May 2025 (95% CI: 72–279). Although 92.4% of laboratory results were released within seven days, only 6.5% met complete surveillance timeliness criteria due to specimen transport delays.
Conclusions: These findings provide empirical evidence to support the introduction of rubella-containing vaccines, targeted catch-up immunization, and strengthening of surveillance logistics to improve outbreak preparedness.

Keywords: Rubella, Spatial analysis, ARIMA, IgM positivity, Seasonality, GIS

INTRODUCTION

Rubella is of public health importance because of the teratogenic potential of infections acquired during pregnancy. Rubella virus is generally recognized as the most common infectious cause of birth defects, accounting for an estimated 100 000 infants born with congenital rubella syndrome (CRS) each year worldwide. Infection with rubella virus within 12 days of conception and early pregnancy (usually within the first 8–10 weeks) may result in miscarriage, fetal death or CRS. For the rest of the population, rubella is an acute, usually mild viral infection transmitted by respiratory droplets, which affects susceptible children and adults worldwide.[1] CRS remains one of the most preventable causes of congenital disability worldwide. Several live, attenuated rubella vaccines are currently available. Most rubella vaccines are administered in combination formulations such as measles-rubella (MR), measles-mumps-rubella (MMR), and measles-mumps-rubella-varicella (MMRV). Considering the global burden of CRS, the proven efficacy, effectiveness and safety of RCVs and regional elimination goals, WHO recommends that countries introduce RCVs into their national immunization programmes. This recommendation includes the opportunity offered by accelerated measles elimination activities to achieve both goals. Countries that have not yet introduced RCV into their immunization programmes should do so if they can achieve a coverage level of 80% or greater, through either routine immunization or campaigns. While opportunities should not be missed, the decision to introduce rubella vaccine in combination with MCV needs careful consideration related to the sustainability of maintaining high RCV coverage into the future.[1] The world health organization (WHO) has incorporated rubella elimination targets into the global measles and rubella strategic framework 2021–2030, emphasizing the integration of RCV into routine immunization systems and the strengthening of case-based surveillance.[2] Despite these global advances, rubella remains endemic in many low- and middle-income countries (LMICs), particularly across sub-Saharan Africa, where vaccine introduction has been delayed or inconsistently implemented.[3]

In sub-Saharan Africa, rubella transmission is shaped by high fertility rates, rapid population growth, urban–rural disparities in healthcare access, and variable immunization coverage.[4-9] Seroprevalence studies from Ethiopia, Uganda, Angola, South Africa, and other African countries demonstrate substantial immunity gaps among children and women of reproductive age.[4-8] A recent meta-analysis estimated that although IgG seroprevalence may appear moderate in some African populations, significant pockets of susceptibility persist, sustaining endemic transmission and periodic outbreaks.[9] These gaps increase the risk of CRS, particularly in countries without routine RCV introduction.

Nigeria presents a particularly critical context for rubella epidemiology. As Africa's most populous nation, with an estimated population exceeding 220 million and one of the highest annual birth cohorts globally, Nigeria provides epidemiologic conditions conducive to sustained rubella circulation in the absence of widespread vaccination.[10,11] Mathematical modeling studies indicate that in high-birth-rate populations, the accumulation of susceptible individuals can generate cyclical outbreaks every few years when routine immunization coverage is inadequate.[12,13] Such cyclical dynamics increase the likelihood of CRS outbreaks during peak transmission periods. Currently, rubella surveillance in Nigeria is embedded within the national measles case-based surveillance framework. Suspected febrile rash illness cases are first tested for measles IgM antibodies, and measles-negative specimens are subsequently tested for rubella IgM.[14,15] While this integrated approach improves operational efficiency, it limits rubella-specific surveillance sensitivity and may underestimate the true burden of infection.[15,16] Moreover, rubella-containing vaccine has not yet been fully integrated into Nigeria's national routine immunization schedule, resulting in continued susceptibility among children and women of reproductive age.[17] In the absence of systematic CRS surveillance and routine RCV coverage, the true epidemiologic burden of rubella remains incompletely characterized. Existing Nigerian studies have largely focused on hospital-based seroprevalence among pregnant women or localized outbreak investigations.[18,19] These studies demonstrate ongoing susceptibility and regional variation in rubella immunity but lack nationally representative spatial and temporal analysis. Consequently, there remains limited evidence on geographic clustering patterns, seasonal transmission windows, and structural surveillance performance at a national scale.

Geospatial epidemiology offers valuable tools for identifying disease hotspots and understanding spatial heterogeneity. Global Moran's I assesses overall spatial autocorrelation, determining whether cases are randomly distributed or clustered, while Getis-Ord Gi statistics identify statistically significant hotspots and cold spots at subnational levels.[20,21] Subnational clustering has been shown to sustain transmission even when national-level vaccination coverage appears adequate.[22,23] Identifying geographic hotspots is therefore essential for targeted immunization campaigns and efficient allocation of limited public health resources.

In addition to spatial heterogeneity, rubella transmission demonstrates seasonal patterns influenced by climatic conditions and social mixing behaviors. Studies from West Africa, East Africa, and Asia have reported seasonal peaks associated with dry-season transitions, school calendar cycles, and meteorological variables such as temperature and humidity.[24-28] Seasonal-trend decomposition using loess (STL) enables separation of long-term trends from recurring seasonal components, providing a clearer understanding of transmission periodicity.[25] Autoregressive Integrated Moving Average (ARIMA) modeling further supports short-term forecasting of disease incidence, enabling anticipatory planning for vaccination campaigns and outbreak response.[13,25]

Surveillance system performance plays a critical role in disease control. WHO standards emphasize timely case detection, specimen collection, laboratory confirmation, and reporting.[29] However, surveillance systems in many LMICs face logistical challenges, particularly delays in specimen transport and limited laboratory capacity.[15,16] Evaluating surveillance timeliness is therefore essential to assess system effectiveness and identify structural weaknesses that may compromise outbreak preparedness. Demographic analysis is also important in understanding rubella transmission dynamics. In settings without routine RCV introduction, rubella transmission typically concentrates among children aged 2–9 years, who act as the primary reservoir of infection.[10,30] If susceptibility extends into adolescence or adulthood, particularly among women of reproductive age, the risk of CRS increases significantly.[9,31] Determining whether rubella positivity is associated with demographic predictors such as age or sex can inform targeted versus universal vaccination strategies. Despite Nigeria's epidemiologic importance, comprehensive national analyses integrating spatial clustering, seasonal dynamics, forecasting, and surveillance quality assessment remain limited. Such integrated approaches are critical for informing evidence-based vaccine policy and strengthening outbreak preparedness.

This study therefore aimed to conduct a comprehensive geospatial and temporal analysis of rubella incidence in Nigeria from 2020 to 2024. Specifically, the objectives were to identify geographic hotspots and assess spatial autocorrelation, characterize seasonal trends and inter-annual variations and evaluate surveillance timeliness and system performance using WHO-defined indicators.

By combining spatial statistics, time-series modeling, and surveillance evaluation, this study provides nationally representative evidence to guide rubella vaccine introduction, optimize catch-up immunization strategies, and strengthen surveillance infrastructure. The findings aim to contribute to Nigeria's progress toward rubella elimination and the prevention of congenital rubella syndrome.

METHODS

Study design and data source

A retrospective observational study was conducted using national rubella surveillance data obtained from Nigeria's integrated measles–rubella surveillance system between January 2020 and December 2024.

The dataset included both suspected and laboratory-confirmed cases reported through the surveillance outbreak response management and analysis system (SORMAS) and processed at the national reference laboratory.

Case definition

A laboratory-confirmed rubella case was defined as a suspected febrile rash illness case testing positive for rubella-specific IgM antibodies. Suspected cases followed the standard WHO case definition for febrile rash illness.

Data management

Data were cleaned and standardized prior to analysis. Records with incomplete or inconsistent key variables (age, location, laboratory result) were assessed and retained where appropriate. Age was categorized into predefined groups (0–<1, 1–<2, 2–<5, 5–9, 10–14, 15–19, ≥20 years). Cases with missing age were analyzed as a separate category.

Spatial analysis

Geospatial analysis was conducted at the state level using geographic information systems (GIS). State-level incidence rates were mapped to visualize geographic distribution. Global spatial autocorrelation was assessed using Moran's I statistic to determine whether rubella cases were spatially clustered, dispersed, or randomly distributed. Local spatial clustering was evaluated using Getis-Ord Gi statistics to identify statistically significant hotspots and cold spots.

Temporal analysis

Monthly rubella case counts were analyzed to assess temporal trends and seasonality. STL was applied to separate trend, seasonal, and residual components of the time series. ARIMA models were fitted to the data to assess temporal patterns and generate short-term forecasts. Model selection was based on standard criteria including AIC and residual diagnostics.

Surveillance performance assessment

Surveillance system performance was evaluated using WHO-recommended timeliness indicators. These included time from symptom onset to sample collection. Time from sample collection to laboratory receipt. Time from laboratory receipt to result reporting. The proportion of cases meeting each timeliness criterion and overall system performance were calculated.

Software

Data analysis was conducted using R (for statistical and time-series analysis), Python (for modeling), and QGIS/ArcGIS (for spatial analysis).

Ethical Considerations

Ethical approval was obtained from the National Health Research Ethics Committee of Nigeria (NHREC), Federal Ministry of Health (protocol number: NHREC/01/01/2007-15/08/2025; approval number: NHREC/01/01/2007-20/10/2025; approved on 20 October 2025). The study utilized secondary de-identified surveillance data, and no direct patient contact occurred.

RESULTS

Burden and demographic distribution

A total of 7,907 suspected rubella cases were identified through the national surveillance database during the study period (January 2020 to December 2024), of which 4,001(50.6%) laboratory-confirmed rubella IgM-positive cases met the study case definition and were included in the final analysis

Geographic distribution of laboratory-confirmed rubella cases

Table 1 presents the regional distribution of rubella IgM test results across Nigeria's six geopolitical zones during the study period. The Southeast recorded the highest proportion of both IgM-negative (21.27%) and IgM-positive cases (21.19%), followed by the Southwest, which accounted for 19.82% and 19.52%, respectively. The Northwest recorded the lowest proportions of both IgM-negative (11.01%) and IgM-positive cases (11.25%). Indeterminate results were few across all regions, with the highest number reported in the north central zone (39 cases).

Figure 1 illustrates the geographic distribution of confirmed rubella cases across the geopolitical zones, demonstrating a greater concentration of reported cases in southern Nigeria compared with parts of the northern region.

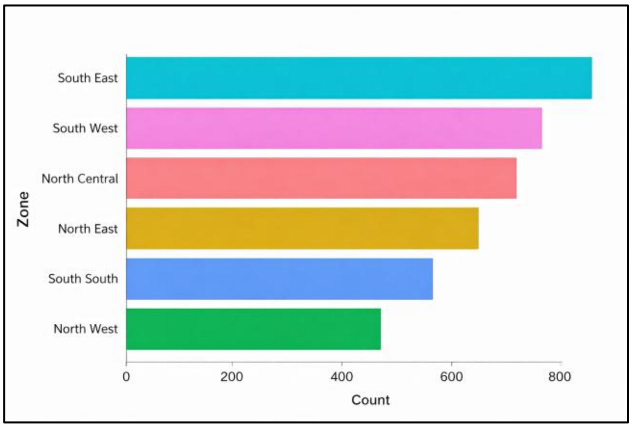

Figure 1: Geopolitical distribution of laboratory-confirmed rubella cases in Nigeria.

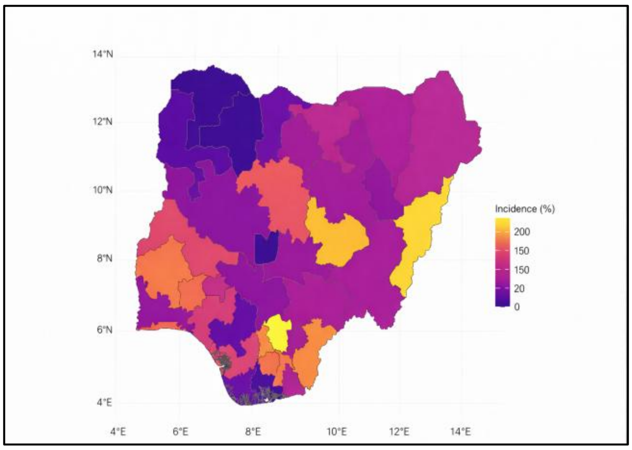

Figure 2: Choropleth map of the spatial distribution of rubella incidence across Nigerian states (2020–2024).

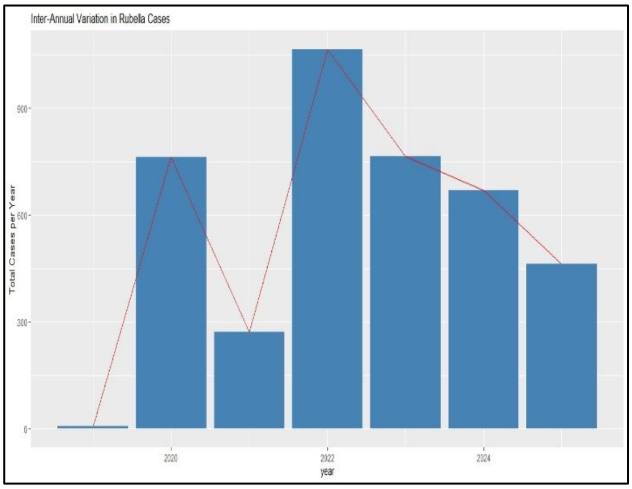

Figure 3: Annual trend in laboratory-confirmed rubella cases in Nigeria (2020–2024).

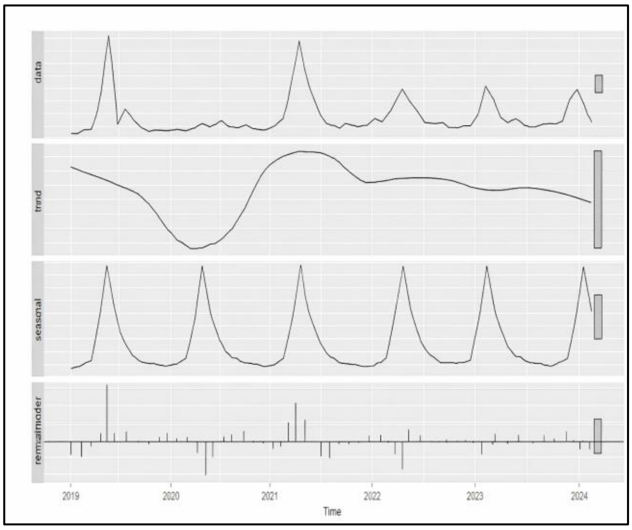

Figure 4: Seasonal-trend decomposition of laboratory-confirmed rubella cases in Nigeria (2019–2024).

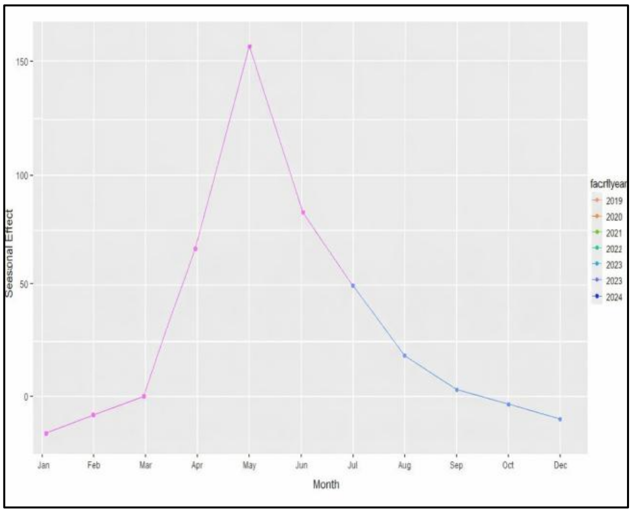

Figure 5: Monthly seasonal effect of laboratory-confirmed rubella cases in Nigeria (2019–2024).

Spatial distribution of rubella incidence

The spatial distribution of rubella incidence showed marked geographic variation across Nigeria (Figure 2). Higher incidence rates were observed in several southern and some central states, while lower incidence rates were recorded in parts of northern Nigeria. Particularly elevated incidence was observed in states such as Ebonyi, Cross River, and Delta, whereas lower incidence rates were seen in Kebbi, Sokoto, and Zamfara. At the state level, Enugu recorded the highest number of confirmed rubella cases (235; 6.06%), followed by Adamawa (220; 5.67%), Plateau (189; 4.87%), and Anambra (188; 4.85%).

Hotspot analysis of laboratory-confirmed rubella cases

Spatial hotspot analysis using the Getis-Ord Gi statistic identified statistically significant spatial clustering of laboratory-confirmed rubella cases across Nigeria (Table 2). Ebonyi State was identified as a statistically significant hotspot (Gi=2.32; p=0.021), indicating a higher-than-expected concentration of rubella cases. In contrast, Kebbi (Gi=−2.33; p=0.020) and Sokoto (Gi=−2.11; p=0.035) were identified as statistically significant cold spots, indicating lower-than-expected clustering of rubella cases compared with surrounding states.

Global spatial autocorrelation analysis

Table 3 presents the results of the Global Moran's I spatial autocorrelation analysis of laboratory-confirmed rubella cases in Nigeria. The Moran's I statistic was 0.1434, indicating weak positive spatial autocorrelation, suggesting that states with similar rubella case burdens tended to be located near one another. However, this clustering did not reach statistical significance (z=1.60; p=0.054). These findings suggest that although some spatial clustering may be present, the overall national distribution of rubella cases did not demonstrate statistically significant global spatial autocorrelation.

Temporal trends in rubella transmission

Figure 3 presents the inter-annual variation in laboratory-confirmed rubella cases in Nigeria. The annual number of cases fluctuated across the study period, with a sharp increase from 2021 to a peak in 2022. The highest number of cases was recorded in 2022, followed by a gradual decline in 2023, and 2024. The lowest number of cases was observed at the beginning of the series, with another marked reduction in 2021.

Seasonal decomposition of rubella transmission

Figure 4 presents the seasonal-trend decomposition of laboratory-confirmed rubella cases in Nigeria from 2019 to 2024. The observed time series shows recurring peaks in rubella cases across the study period, indicating temporal fluctuation in case occurrence. The trend component demonstrates an initial decline followed by an increase, reaching a peak around 2021, after which a gradual decline was observed. The seasonal component reveals a consistent repeating annual pattern, with pronounced peaks occurring at similar periods each year, suggesting strong seasonality in rubella occurrence.

Seasonal pattern of laboratory-confirmed rubella cases in Nigeria by calendar month (2019–2024)

Figure 5 presents the monthly seasonal pattern of laboratory-confirmed rubella cases in Nigeria from 2019 to 2024. A clear seasonal pattern was observed, with case occurrence increasing from April and peaking in May, followed by a steady decline from June through December. The seasonal effect was lowest between October and January.

Forecasted monthly rubella cases using autoregressive integrated moving average model

The ARIMA model forecasted the monthly distribution of laboratory-confirmed rubella cases in Nigeria from August 2024 to July 2025 (Table 4). Forecasts indicated relatively low transmission between August 2024 and March 2025, followed by a pronounced seasonal increase beginning in April 2025.

The highest projected burden was forecast for May 2025 (175.6 cases; 95% CI: 72.4–278.8), followed by June 2025 (126.6 cases; 95% CI: 23.4–229.8) and April 2025 (82.8 cases; 95% CI: −20.4–186.0). These projections are consistent with the observed seasonal pattern and suggest persistent second-quarter increases in rubella transmission.

Table 1: Distribution of laboratory-confirmed rubella cases by geopolitical zone, Nigeria (2020–2024).

Region	IgM negative	IgM positive	Indeterminate	% of total IgM negative	% of total IgM positive
North central	695	734	39	17.79	18.35
Northeast	639	648	9	16.36	16.2
Northwest	430	450	20	11.01	11.25
Southeast	831	848	17	21.27	21.19
South South	537	540	3	13.75	13.5
Southwest	774	781	7	19.82	19.52

Table 2: Getis-Ord Gi hotspot analysis of laboratory-confirmed rubella cases across Nigerian states.

State	Positive cases	Gi star score	P value	% of total cases
Kebbi	40	-2.3317	0.0197	1.03
Ebonyi	90	2.3226	0.0210	2.32
Sokoto	19	-2.1082	0.0350	0.49
Niger	68	-1.9312	0.0535	1.75
Zamfara	9	-1.8254	0.0679	0.23
Kaduna	139	-1.8251	0.0679	3.58
Abia	175	1.7346	0.0821	4.51
Ogun	84	1.4717	0.1411	2.17
Rivers	20	1.2743	0.2025	0.52
Anambra	188	0.9811	0.3265	4.85
Jigawa	104	-0.9754	0.3294	2.68
Enugu	235	0.8996	0.3683	6.06
Edo	54	0.8639	0.3876	1.39
Katsina	57	-0.8235	0.4102	1.47
Benue	86	0.7887	0.4303	2.22
Imo	160	0.7572	0.4499	4.12
Federal capital territory	0	-0.7554	0.4499	0.00
Taraba	84	-0.7408	0.4588	2.17
Borno	96	0.7033	0.4815	2.47
Osun	151	0.6782	0.4977	3.89
Bayelsa	63	-0.6713	0.5020	1.62
Akwa Ibom	82	0.6312	0.5279	2.11
Delta	138	-0.5714	0.5677	3.56
Yobe	88	-0.5513	0.5814	2.27
Adamawa	220	-0.5309	0.5955	5.67
Oyo	154	0.5123	0.6084	3.97
Nasarawa	75	-0.5101	0.6100	1.93
Ekiti	112	0.4628	0.6435	2.89
Gombe	76	0.3593	0.7194	1.96
Kano	82	-0.3415	0.7327	2.11
Lagos	155	-0.3304	0.7433	4.00
Kwara	125	0.2667	0.7895	3.22
Plateau	189	-0.2597	0.7561	4.87
Cross River	183	0.2063	0.8366	4.72
Bauchi	84	0.1723	0.8616	2.17
Ondo	125	-0.1342	0.8932	3.22
Kogi	69	0.0613	0.9511	1.78

Table 3: Global Moran's I spatial autocorrelation analysis of laboratory-confirmed rubella cases in Nigeria.

Statistic	Value	Interpretation
Moran I statistic	0.143355	Observed spatial autocorrelation
Expectation	-0.027778	Expected value under random distribution
Variance	0.011379	Variance under null hypothesis
Standard deviate	1.604300	Z-score for significance testing
P value	0.054320	Significance level (alternative: greater)

Table 4: ARIMA forecast of monthly laboratory-confirmed rubella cases in Nigeria (April-June 2025).

Month	Point forecast	95% confidence interval
April 2025	82.8	-20.4 to 186.0
May 2025	175.6	72.4 to 278.8
June 2025	126.6	23.4 to 229.8

DISCUSSION

This study assessed the geospatial distribution, spatial clustering, temporal pattern, seasonality, and forecasted trend of laboratory-confirmed rubella cases in Nigeria during the pre-rubella-containing vaccine period. A total of 4,001 laboratory-confirmed IgM-positive cases were analysed from 2020 to 2024, showing that rubella was widely distributed across Nigeria but with clear regional and state-level variation. The Southeast recorded the highest proportion of IgM-positive cases (848; 21.19%), followed by the Southwest (781; 19.52%) and North Central (734; 18.35%), while the Northwest recorded the lowest proportion (450; 11.25%). This pattern suggests that rubella burden was not evenly distributed across the country and may reflect differences in population density, surveillance performance, health-seeking behaviour, or underlying immunity gaps.[16] Similar evidence from South-East Nigeria using measles laboratory surveillance also confirmed continued rubella circulation, with children under 10 years accounting for over 80% of confirmed cases.[10,32]

The state-level analysis further demonstrated marked spatial variation. Enugu recorded the highest number of confirmed cases (235; 6.06%), followed by Adamawa (220; 5.67%), Plateau (189; 4.87%), and Anambra (188; 4.85%). However, the hotspot analysis showed that high case counts alone did not necessarily indicate statistically significant clustering. Ebonyi, despite having fewer confirmed cases than Enugu or Adamawa, was the only statistically significant hotspot (Gi=2.32; p=0.021), while Kebbi (Gi=−2.33; p=0.020) and Sokoto (Gi=−2.11; p=0.035) were significant cold spots. This distinction is important because it shows that hotspot analysis identifies spatial clustering relative to neighboring areas, not simply the states with the highest number of cases.

The Global Moran's I result provides additional context. The Moran's I statistic was 0.1434, indicating weak positive spatial autocorrelation, but this did not reach statistical significance (z=1.60; p=0.054). This means that although there were localized clusters, the overall national spatial distribution of rubella cases was not strongly clustered. This agrees with the Getis-Ord Gi findings, where only a few states showed statistically significant local clustering. Therefore, the Nigerian pattern appears to be characterized more by localized pockets of elevated or reduced clustering than by a strong nationwide spatial pattern.[25]

The temporal analysis showed substantial annual fluctuation in confirmed rubella cases. The highest burden occurred in 2022, while a decline was observed in subsequent years. Such fluctuation is expected in settings without long-established rubella vaccination, where susceptible populations may accumulate over time and contribute to periodic increases in cases.[12,31] This pattern is comparable to findings from Ethiopia's pre-vaccination era, where rubella cases identified through measles case-based surveillance also showed temporal variation and persistent circulation in the absence of routine rubella vaccination.[5,23]

Seasonality was another important finding. The STL decomposition and monthly seasonal analysis showed that rubella cases increased from April and peaked around May before declining through the later months of the year. This is broadly consistent with the Ethiopian study, which reported seasonal peaks in laboratory-confirmed rubella cases during the hot dry months from January to June. However, the exact peak month differs, suggesting that seasonal rubella patterns may vary by country, climate, social mixing, school calendar, and surveillance practices.[5,22,24,33]

The ARIMA forecast projected a seasonal rise in cases during the second quarter of 2025, with the highest forecast in May 2025 (175.6 cases), followed by June 2025 (126.6 cases) and April 2025 (82.8 cases). This forecast is consistent with the observed seasonal pattern, where rubella activity peaked around April–May. However, the wide confidence intervals and negative lower bounds in some months show uncertainty in the forecast and should be interpreted cautiously. Since rubella cases are count data, future forecasting may benefit from models that better handle non-negative infectious disease counts.[34]

The findings also have important policy relevance. Globally, reported rubella cases declined by 81%, from 93,816 in 2012 to 17,407 in 2022, as rubella-containing vaccine introduction expanded across countries.[17] By 2022, 175 of 194 WHO countries had introduced rubella-containing vaccines, and 98 countries had verified rubella elimination.[17] Nigeria's continued rubella circulation in this study therefore supports the need for effective introduction and sustained high coverage of rubella-containing vaccine, supported by strong surveillance and subnational targeting.[17,35]

Strengths

This study has several strengths, including the use of nationally representative surveillance data, the integration of geospatial and time-series analytical approaches, and the assessment of surveillance system performance using standardized WHO indicators. These methods provide a comprehensive understanding of rubella epidemiology in Nigeria.

Limitations

However, several limitations should be acknowledged. First, the use of secondary surveillance data may be subject to underreporting and misclassification, particularly given the integration of rubella surveillance within measles reporting systems. Second, the analysis was conducted at the state level, which may mask finer-scale transmission patterns at the local government or community level. Third, key variables such as vaccination status, socioeconomic factors, and healthcare access were not available, limiting the ability to fully explore determinants of transmission. Despite these limitations, the findings provide valuable insights to inform rubella control efforts in Nigeria.

CONCLUSION

This study demonstrates that rubella transmission in Nigeria remains characterized by spatial heterogeneity, seasonal recurrence, and surveillance challenges during the pre-RCV era. The identification of localized hotspots and predictable seasonal peaks provides evidence to support rubella-containing vaccine introduction, targeted catch-up immunization, and strengthened surveillance logistics to improve outbreak preparedness and progress toward rubella elimination.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: The study was approved by the Institutional Ethics Committee

REFERENCES

1. World Health Organization. Rubella vaccines: WHO position paper – July 2020. Wkly Epidemiol Rec. 2020;95(27):301–24.
2. Measles and rubella strategic plan 2021–2030. 2021. Available at: https://www.who.int/publications/i/item/measles-and-rubella-strategic-framework. Accessed on 21 January 2026.
3. Masresha BG, Wiysonge CS, Katsande R, O'Connor PM, Lebo E, Perry RT. Tracking Measles and Rubella Elimination Progress—World Health Organization African Region, 2022–2023. Vaccines. 2024;12(8):949.
4. Tahita MC, Hübschen JM, Tarnagda Z, Ernest D, Charpentier E, Kremer JR, et al. Rubella seroprevalence among pregnant women in Burkina Faso. BMC Infect Dis. 2013;13(1):164.
5. Tamirat B, Hussen S, Shimelis T. Rubella virus infection and associated factors among pregnant women attending the antenatal care clinics of public hospitals in Hawassa City, Southern Ethiopia: a cross-sectional study. BMJ Open. 2017;7(10):16824.
6. Wondimeneh Y, Tiruneh M, Ferede G, Abera B. Rubella virus infections and immune status among pregnant women in Ethiopia. Int J Infect Dis. 2018;12:1971.
7. Taku NA, Ndze VN, Abernathy E, Hao LJ. Seroprevalence of rubella virus antibodies among pregnant women in Cameroon. PLOS One. 2019;10:594
8. Vueba A, Faria C, Almendra R, Santana P, Sousa MDC. Seroepidemiology study of Cytomegalovirus and Rubella in pregnant women in Luanda, Angola: geospatial distribution and its association with socio-demographic and clinical-obstetric determinants. BMC Infect Dis. 2022;22(1):124.
9. Kassa ZY, Hussen S, Asnake S. Sero-prevalence of rubella among pregnant women in Sub-Saharan Africa: a meta-analysis. Hum Vaccines Immunother. 2020;16(10):2472–8.
10. Durowade K, Musa O, Osagbemi G. Rubella transmissibility and reproduction number (Ro): A critical appraisal of the prospects for its control in Nigeria. Niger Postgrad Med J. 2020;27(3):156.
11. Rozhnova G, Metcalf CJE. Characterizing the dynamics of rubella relative to measles: the role of stochasticity. J R Soc Interface. 2013;10(86):2643.
12. Motaze NV, Mthombothi ZE, Adetokunboh O. Impact of rubella vaccine introduction: a systematic review of modelling. Vaccines. 2021;20:7684.
13. Winter AK, Lambert B, Klein D, Klepac P. Feasibility of measles and rubella vaccination programmes for disease elimination: A modelling study. Lancet Glob Health. 2022;10(12):1681–91.
14. Durowade K, Musa O, Jimoh M, Salaudeen A, Bolarinwa O, Bakare O, et al. Burden, epidemiological pattern, and surveillance gap of rubella in Nigeria: A call for routine vaccination policy. Indian J Health Sci Biomed Res KLEU. 2021;14(1):31.
15. Omoleke S, Udenenwu H. Analysis of rubella surveillance data in Kebbi State, Nigeria, 2014–2015. Ann Health Res. 2016;2(2):76–83.
16. Masresha B, Wiysonge C, Katsande R, others. Tracking Measles and Rubella Elimination Progress—World Health Organization African Region, 2022–2023. Vaccines. 2024;12(8):949.
17. World Health Organization, United Nations Children's Fund. WHO–UNICEF estimates of national immunization coverage (WUENIC): Nigeria. Geneva: WHO. 2024. Available at: https://immunizationdata.who.int. Accessed on 21 January 2026.
18. Suleiman S, Bakare R, Akanbi A, Fowotade A, Billiaminu S, Durowade K. Recent rubella infection among childbearing women in a tertiary hospital in Nigeria: A seroepidemiological indication for vaccination need. Afr J Clin Exp Microbiol. 2016;17(3):213.
19. Owolabi BO, Adesina KT, Adesiyun OO, Fadeyi A, Olarinoye AO, Suleiman ST, et al. Perinatal outcome of pregnant mothers with active rubella infection in a tertiary hospital in Nigeria. Ghana Med J. 2025;59(1):15–21.
20. Tushabe P, Bwogi J, Abernathy E, Birungi M, Eliku JP, Seguya R, et al. Descriptive epidemiology of rubella disease and associated virus strains in Uganda. J Med Virol. 2020;92(3):279–87.
21. Getis A, Ord JK. The analysis of spatial association by use of distance statistics. Geogr Anal. 1992;24(3):189–206.
22. Metcalf CJE, Cohen C, Lessler J. Implications of spatially heterogeneous vaccination coverage for the

risk of congenital rubella syndrome in South Africa. J R Soc Interface. 2013;2:1275.
23. Getahun M, Beyene B, Gallagher K, Ademe A. Epidemiology of rubella virus cases in the pre-vaccination era of Ethiopia, 2009–2015. BMC Publ Heal. 2016;11:868.
24. Ma Y, Liu K, Hu W, Song S, Zhang S. Epidemiological characteristics, seasonal dynamic patterns, and associations with meteorological factors of Rubella in Shaanxi Province, China, 2005–2018. Am J Trop Med Hyg. 2020;104(1):321–9.
25. Zheng J, Zhang N, Shen G, Liang F. Spatiotemporal and seasonal trends of class A and B notifiable infectious diseases in China: retrospective analysis. JMIR Public Health Surveill. 2023;9(1):42820.
26. Jallow MM, Sadio BD, Mendy MP, Sy S, Fall A, Kiori D, et al. Measles and Rubella Incidence and Molecular Epidemiology in Senegal: Temporal and Regional Trends during Twelve Years of National Surveillance, 2010–2021. Viruses. 2022;14(10):2273.
27. Blake A, Djibo A, Guindo O, Bharti N. Investigating persistent measles dynamics in Niger and associations with rainfall. J R Soc Interface. 2020;17(169):480.
28. Goodson JL, Masresha B, Dosseh A, Byabamazima C, Nshimirimana D, Cochi S, et al. Rubella Epidemiology in Africa in the Prevaccine Era, 2002–2009. J Infect Dis. 2011;204(1):215–25.
29. Measles and rubella strategic framework 2021–2030. Geneva: WHO. Available at: https://www.who.int/publications. Accessed on 21 January 2026.
30. World Health Organization. Rubella vaccines: WHO position paper – July 2020. Wkly Epidemiol Rec. 2020;95(27):301–24.
31. Patel MK, Antoni S, Danovaro-Holliday MC, Goodson JL, Kretsinger K, Sodha SV, et al. The epidemiology of rubella, 2007–18: an ecological analysis of surveillance data. Lancet Glob Health. 2020;8(10):1226–35.
32. Fatiregun AA, Fagbamigbe AF, Adebowale AS. Epidemiology of rubella disease in south-west nigeria: trends and projection from measles case-based surveillance data. South Afr J Infect Dis. 2014;29(2):60–4.
33. Takashima Y, Aslam SK, Evans R, Mariano KM, Lee C won, Wang X, et al. Measles and Rubella Elimination in the Western Pacific Region in 2013–2022: Lessons Learned from Progress and Achievements Made during Regional and Global Measles Resurgences. Vaccines. 2024;12(7):817.
34. Siamba S, Otieno A, Koech J. Application of ARIMA, and hybrid ARIMA Models in predicting and forecasting tuberculosis incidences among children in Homa Bay and Turkana Counties, Kenya. Schmidt T, editor. PLOS Digit Heal. 2023;2(2):84.
35. Rodriguez-Cartes SA, Zhang Y, Mayorga ME, Swann JL, Allaire BT. Evaluating the potential impact of rubella-containing vaccine introduction on congenital rubella syndrome in Afghanistan, Dem. Republic of Congo, Ethiopia, Nigeria, and Pakistan: A mathematical modeling study. PLOS Glob Publ Heal. 2024;4(1):2656.

Cite this article as: Fahad MS, Aliyu AA, Reigns AN, Ugwu DC, Okunromade O. Spatiotemporal dynamics, hotspot identification and surveillance performance of rubella in Nigeria. Int J Community Med Public Health 2026;13:4140-8.