



PROJECTION OF MATERNAL MORTALITY RATE FOR SIERRA LEONE USING THE MULTILAYER PERCEPTRON

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Abstract

This research article employs annual time series data on MMR for Sierra Leone from 1985 to 2023 to predict future trends of MMR over the period 2024 to 2035. The forecast evaluation criteria of the applied model indicate that the ANN (12, 12, 1) model is stable. The neural network model projections revealed that MMR is expected to increase and remain very high throughout the out of sample period. Therefore, we encourage the government to adopt the suggested 5-fold policy prescription.

Keywords: ANN, Forecasting, Maternal Mortality Ratio.

Introduction

Maternal death is defined as the demise of a woman while pregnant or within 42 days of the termination of their pregnancy, regardless of the duration and site of pregnancy, from any cause related to or aggravated by the pregnancy or its management but not from accidental or incidental causes (Ministry of health and Sanitation, 2015). In 2017, there were an estimated 295,000 maternal deaths worldwide in comparison to 451,000 deaths in 2000. The global maternal mortality ratio, decreased from 342 in 2000 to 211 per 100,000 live births in 2017 (WHO, 2019). Despite this achievement, many women die from serious health problems during pregnancy and childbirth. Most of these deaths are reported in low- and middle-income countries, with two-thirds occurring in sub-Saharan Africa (WHO, 2016; WHO, 2015). In 2017, Sierra Leone reported the highest maternal mortality ratio in West Africa, with 1,120 maternal deaths per 100,000



live births (WHO, 2019). A woman in Sierra Leone faces a lifetime risk of 1 in 7 of dying from pregnancy or childbirth, and maternal deaths account for 36% of all deaths among women aged 15-49 (SDHS 2012). The objective of this paper is to model and forecast MMR for Sierra Leone using a machine learning approach. The findings of this piece of work will inform policy making and allocation of adequate resources to the maternal and child health program with a view to further reduce preventable maternal deaths.

Literature Review

Author(s)	Objective(s)	Methodology	Key finding(s)
Compaoré et al. (2025)	to determine the frequencies and causes of severe maternal outcomes (SMO: MNM + MD) in regional and district hospitals in Benin, Burkina Faso and Niger	Between 1st February 2008 and 31st October 2010, we conducted an SMO incidence study in 36 hospitals in the three countries	-At the time of our study the burden of severe maternal outcomes was high in Benin, Burkina Faso and Niger. -most women had a near miss complication on admission to a participating hospital, indicating the need to facilitate access to obstetric care for women with high-risk pregnancies and complications
Ezeanochie et al. (2025)	To identify factors associated with maternal mortality in Sierra Leone	this was a retrospective review of 86 consecutive maternal deaths at the Princess Christian Maternity Hospital (PCMH), Freetown from October 2022 to September 2023	Maternal mortality remains a public health problem in PCMH Freetown. Hypertensive disorders of pregnancy and postpartum hemorrhage are the leading causes. Delay in accessing or receiving care are contributory to maternal mortality
Kawuki et al. (2025)	examines the relationship between maternal mass media exposure and two critical child health indicators: morbidity and mortality	This secondary analysis of the 2017/2018 Benin Demographic and Health Survey (BDHS) included 13,851 women. Childhood morbidity (fever, cough, and diarrhea) and mortality were analyzed as outcomes. Bivariable and multivariable logistic regression and Cox regression models were applied, and results were expressed as odds ratios (OR), hazard ratios (HR), and their adjusted counterparts	Maternal exposure to mass media, particularly radio and television, was associated with increased childhood morbidity. This association could reflect heightened maternal health awareness, leading to increased reporting of symptoms or exposure to misleading health information through media content



Modern American Journal of Medical and Health Sciences

ISSN (E): 3067-803X

Volume 2, Issue 6, June 2026

Website: usajournals.org

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Thiam et al. (2025)	to evaluate the emergency obstetric care in a maternity peripheral and analyze trends evolving in order to offer solutions to improve the quality of care	This was a retrospective longitudinal descriptive study from 1 January 2011 to 31 December 2024, a period of 15 years	The maternal mortality rate was 503 for 100,000 Live Births. 78% of cases were direct causes and 22% were indirect
Harsono et al. (2024)	to identify structural barriers to maternal care during the early adaptation of the mobile Medical Information Service via Telephone (mMIST) program in Cameroon	conducted in-depth interviews and focus groups with 56 key stakeholders including previously and currently pregnant women, primary healthcare providers, administrators, and representatives of the Ministry of Health, recruited by purposive sampling. Thematic coding and analysis via modified grounded theory approach were conducted using NVivo12 software	Dynamic inter-relations among structural level factors create barriers to maternity care in Cameroon
Birabwa et al. (2024)	To describe the trends in IMMR between 2016 and 2021, and the causes and characteristics of maternal deaths in Kampala, Uganda	-retrospective study utilized routine data from all facilities in Kampala that provided childbirth services from 2016 to 2021. -conducted descriptive analysis and assessed time trends in IMMR	IMMR in Kampala increased from 2019-2021. Health infrastructure changes and maternal health initiatives potentially accounted for the observed trend by affecting data quality. Referral and facility readiness were underlying reasons for maternal deaths
Kamara et al. (2024)	To evaluate the Maternal Death Surveillance and Response (MDSR) system's effectiveness by assessing key surveillance attributes	A descriptive cross-sectional evaluation assessed Sierra Leone's MDSR system from October to November 2019, reviewing 2018 data	Overall, the MDSR system partially meets its objective of obtaining and using information to guide public health actions. The system was useful and acceptable but not simple. Delays in MDs notification and poor data quality may negatively affect the system in reporting accurate and timely information
Saffa et al. (2024)	to examine factors contributing to delays in accessing maternal delivery services as perceived by women in Sierra Leone	community-based survey	This study revealed a high prevalence of perceived delays one and two for mothers to access obstetric services. Delays were mainly related to transport difficulties, low knowledge of pregnancy-related



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			complications, and costly obstetric services
Agballa et al. (2023)	to determine the hospital-based maternal mortality ratio and factors associated with maternal deaths	conducted a case-control study over two years from 1st January 2020 to 31 December 2021 in four Cotonou hospitals. It included 264 maternal deaths (case) matched to 264 controls by delivery mode. The dependent variable was the status at discharge. Independent variables included socio-demographic characteristics, gynecological information, medical and gynecologic history as well as type of complications. Univariate and multivariate analysis were performed to identify the factors associated with maternal deaths	The hospital-based maternal mortality ratio was 1403 deaths per 100,000 live births. Age superior than or equal to 30 years old (OR= 3.09; 95% CI= 1.52 to 6.41; p=0.002), admission by a referral from public health facility (OR=4.26; 95% CI= 2.60-7.10; or private health facility (OR= 4.52; 95% CI= 2.49-8.38 ; gestational age less than or equal to 31 weeks (OR=3.77; 95% CI= 2.13 to 6.84 ; occurrence of non-infectious (OR= 1.94; 95% CI= 1.27 to 2.97; p= 0.002) and fetal complications (OR= 1.98; 95% CI= 1.13 to 3.54; p=0.018) were the factors associated to maternal deaths.
Touolak et al. (2023)	To analyze the factors associated with maternal mortality that occurred at the Gyneco-Obstetric and Pediatric Hospital of Yaounde (YGOPH) from the 1st January 2018 to the 31st December 2021.	conducted an analytical case control study with a retrospective data collection, using medical files of 210 participants (for 1 case, 2 survivors, totally 70 cases and 140 survivors). Data were collected using a questionnaire and analyzed with SPSS 25.0. A multivariate analysis was done to determine the independent factors associated with maternal mortality at YGOPH	Maternal mortality at YGOPH was explained by the following among other factors: Hypertensive disorders (AHR=3.304; P-value=0.019; 95%; CI=[1.401; 5.020]), Comorbidities (AHR=3.01; P-value = 0.003; 95%; CI= [2.059; 3.900]), mode of delivery (AHR=2.900; P-value=0.002; 95%; CI=[4.652; 8.549]), Postpartum hemorrhage (AHR=3.700; P-value = 0.011; 95%; CI= [1.730; 4.002]), Infections (AHR=9.489; P-value=0.004; 95%; CI=[3.552; 12.519])
Diop et al. (2023)	to determine the epidemiological, clinical, and paraclinical profile of maternal deaths recorded in the Tambacounda region, Senegal, during the year 2023	retrospective and descriptive study	This study revealed a high maternal mortality rate (284 deaths per 100,000 live births) in the Tambacounda region, especially among women aged 20 to 24 years (31.1%) and primigravida (30.1%), with deficiencies in prenatal care and examinations



Tsawe et al. (2022)	To estimate inequalities in maternal healthcare use in Sierra Leone	Used cross-sectional study data from 2008, 2013, and 2019 Demographic and Health Surveys (DHS)	inequalities in the selected health indicators favored women from wealthy households, educated women, as well as women from urban areas
Diouf et al. (2021)	to suggest strategic plans that would help decrease maternal and perinatal mortality in the suburbs. It is a descriptive study that shows the different causes of maternal deaths during pregnancy and puerperium period.	retrospective descriptive study done between January 1st 2016 and the 31st of December 2018 in Dakar, Senegal	preeclampsia and its complications are the leading cause of maternal deaths in suburban settings
Musarandega et al. (2021)	to identify the leading causes of maternal deaths using the international classification of disease – 10th revision, for maternal mortality (ICD-MM)	Systematic literature review	Obstetric hemorrhage, hypertensive disorders in pregnancy, non-obstetric complications, and pregnancy-related infections are the leading causes of maternal deaths in SSA
Anyaruna & Enaruna (2020)	to identify current and emerging causes of MM and to examine the recent trend in the etiology of MM University of Benin Teaching Hospital	-The case records of patients who suffered MM in the University of Benin Teaching Hospital, Benin City, Nigeria from 1st January, 2011 to 31st December, 2018 were retrospectively studied -Data on sociodemographic characteristics, clinical diagnosis, and primary cause of maternal death were extracted and analyzed	-A progressive decline in MMR was observed in the initial 5 years, with 58% reduction between 2012 (1.48%) and 2015 (0.61%). A further rise in MMR occurred in the last 3 years, climbing 53% from 2016 (0.81%) to 2018 (1.72%) -Maternal mortality occurred in 235 women during the study period, giving a MMR of 1.1% (1,114/100,000 live births). MMR among booked women of 161/100,000 live births was 6 times lower than MMR for referred women of 953/100,000 live births. Almost half (48%) of the MM occurred within 24 hours of admission to hospital, and 74.5% were postpartum. A teenager had 3-fold risk of mortality, age older than 35 years increased risk of dying 2-fold, and grand-multiparity conferred a 3-fold risk of mortality. Those in the lower socioeconomic class were 7



Modern American Journal of Medical and Health Sciences

ISSN (E): 3067-803X

Volume 2, Issue 6, June 2026

Website: usajournals.org

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			times more likely to suffer mortality
Meh et al. (2020)	To explore ratios and determinants of maternal mortality in women of childbearing age (15–49 years) and assessed differences between the North and South Cameroon	-used the Cameroon Demographic and Health Surveys (2004 and 2011) to extract a sample of 18,665 living or deceased women who had given birth -applied logistic regression	Maternal mortality ratios and determinants varied between women of childbearing age in the North and South of Cameroon
Wirsiy et al. (2019)	to assess the critical determinants of maternal mortality in Cameroon so as to facilitate inform decision making in regards to interventions on maternal health	Systematic review	Maternal age, parity, post-partum hemorrhage, unsafe abortion, domestic violence, hypertensive disorders of pregnancy, severe malaria, HIV/AIDS, inadequate antenatal care, pre-existing co-morbidities, place of delivery, education level, healthcare provider qualification, delays in arrival at health facilities, ectopic pregnancy, placenta previa, anemia, pneumonia, heart disease, number of prenatal visits
Yaya et al. (2018)	To comparatively explore the utilization level of maternal health care, and examine disparities in the determinants of major maternal health outcomes.	used data from two rounds of Benin Demographic and Health Survey (BDHS) to examine the utilization and disparities in factors of maternal health care indicators using logistic regression models	The results of multivariable logistic regression models showed disparities in maternal health care service utilization, including antenatal care, facility-based delivery, postnatal care and contraceptive use across selected maternal factors. The current BHDS showed age, region, religion was significantly associated with maternal health care services

Methodology

The Artificial Neural Network (ANN) approach, which is flexible and capable of nonlinear modelling; will be applied in this study. The ANN is a data processing system consisting of a large number of highly interconnected processing elements in architecture inspired by the way biological nervous systems of the brain appear like. Since no explicit guidelines exist for the determination of the ANN structure, the study applies the popular ANN (12, 12, 1) model based on the hyperbolic



tangent activation function. This paper applies the Artificial Neural Network (ANN) approach in predicting annual maternal mortality ratio (MMR) for Sierra Leone.

Data Issues

This study is based on annual MMR in Sierra Leone for the period 1985 – 2023. The out-of-sample forecast covers the period 2024 – 2035. All the data employed in this research paper was gathered from the World Bank online database.

Findings of the study

ANN Model Summary

Table 1: ANN model summary

Variable	S
Observations	27 (after adjusting endpoints)
Neural Network Architecture:	
Input Layer Neurons	12
Hidden Layer Neurons	12
Output Layer Neurons	1
Activation Function	Hyperbolic Tangent Function
Back Propagation Learning	
Learning Rate	0.005
Momentum	0.05
Criteria:	
Error	0.007205
MSE	276.324113
MAE	13.161637

Residual Analysis for the Applied Model

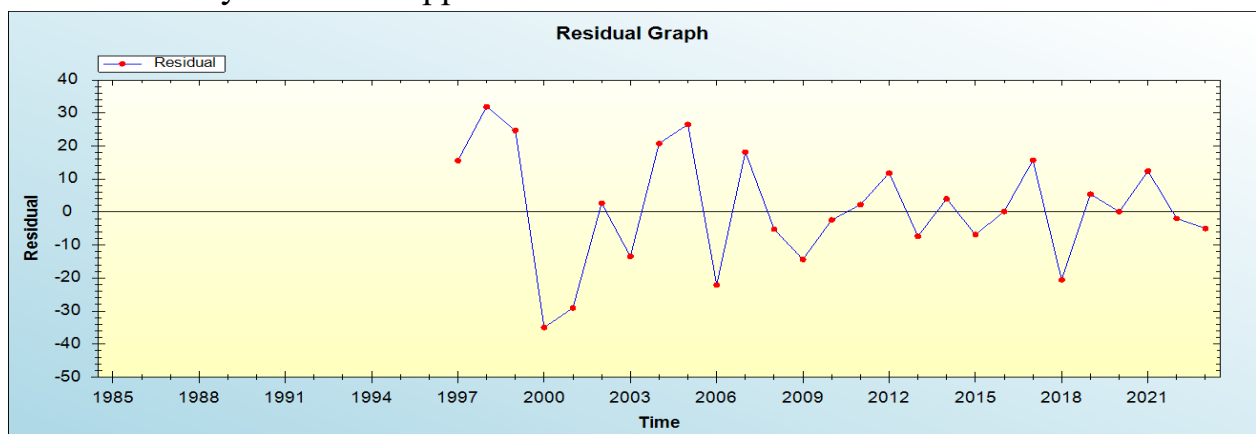


Figure 1: Residual analysis



In-sample Forecast for S

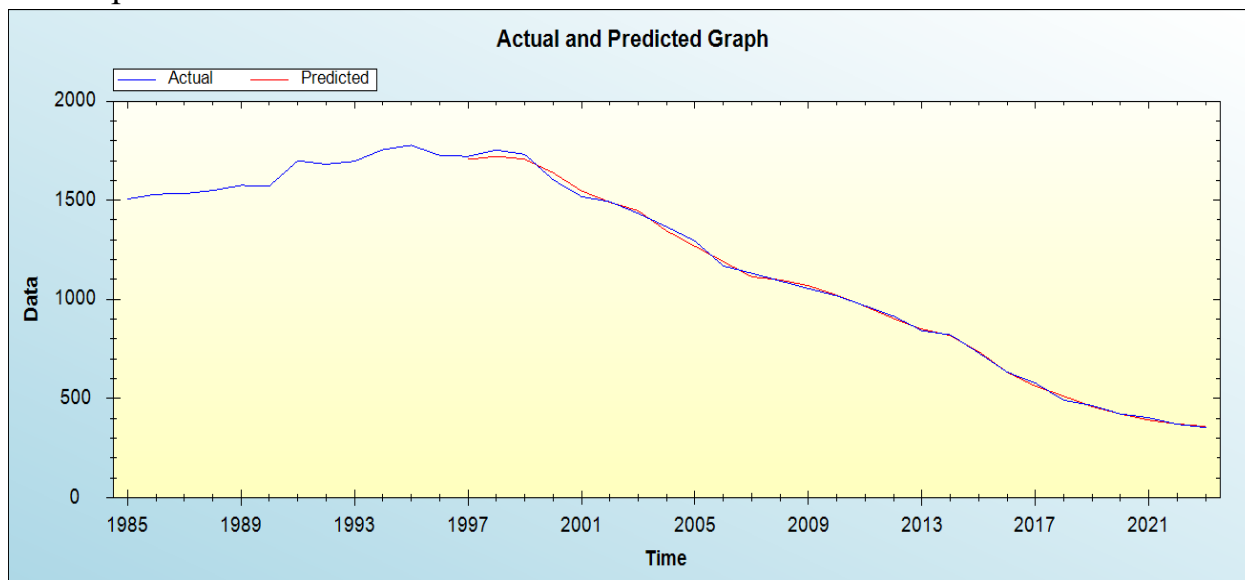


Figure 2: In-sample forecast for the S series

Out-of-Sample Forecast for S: Actual and Forecasted Graph

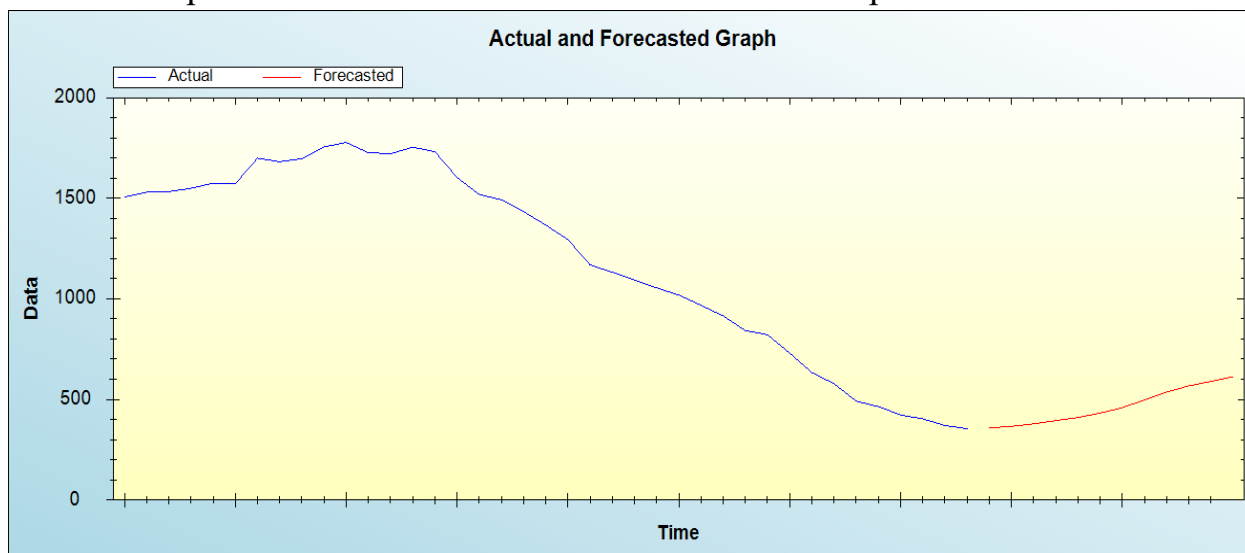


Figure 3: Out-of-sample forecast for S: actual and forecasted graph



Out-of-Sample Forecast for S: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	358.0857
2025	365.2890
2026	378.3608
2027	394.1961
2028	409.7508
2029	431.8023
2030	458.2157
2031	497.1811
2032	535.9870
2033	567.1388
2034	589.1686
2035	612.1427

The main results of the study are shown in table 1. It is clear that the model is stable as confirmed by evaluation criterion as well as the residual plot of the model shown in figure 1. It is projected that annual MMR is expected to increase and remain very high over the out of sample period.

Recommendations & Conclusion

High maternal mortality rates in Sierra Leone are clear evidence that several challenges remain unresolved along the continuum of care. This paper applied a machine learning technique to model and forecast MMR and results indicate that MMR is expected to increase and remain very high in the out of sample period. Hence, we implore authorities to adopt the following policy prescription: : (1) end adolescent pregnancy by enforcing laws that prohibit early child marriage, promote female education and comprehensive sexual and reproductive health education in schools (2) Improve coverage of maternal and child health services across the country (3) direct resources towards the implementation of quality improvement strategies (4) ensure availability of adequate medical supplies and medical staff in all medical facilities and (5) establish posts for obstetricians at government general or district hospitals particularly at high volume sites so that



specialist services are accessed at the first referral level. Alternatively, Registrars undergoing Obstetrics & Gynecology training can be attached at high volume district hospitals under the supervision of provincial consultants.

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