

ANNUAL MATERNAL MORTALITY RATE APPROXIMATION FOR MALAWI USING THE MULTILAYER PERCEPTRON

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ABSTRACT

This research article employs annual time series data on MMR for Malawi 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 will 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

According to the World Health Organization, MMR in Malawi stood at 381 maternal deaths per 100,000 live births in 2020 (WHO, 2023). This was a 49% decrease from 749 in 2000 and a 13% decrease from the previous rate of 439 in 2017, according to the National Demographic Health Survey (NSO, 2011). Despite this tremendous effort, progress to reduce rates has slowed and the MMR ratio has plateaued. Malawi's MMR is still very high despite a significant increase in antenatal care attendance and skilled birth attendance at 97% (NSO, 2021). High levels of medical facility births offer an opportunity for the provision of facility-level strategies to improve the quality of maternity care services. The majority of maternal deaths in Malawi are preventable and emanate from sepsis, obstetric bleeding, and eclampsia, as revealed in the recent report on maternal deaths in Malawi (Riches, 2023; Mgawadere et al. 2016; Geubbels, 2006). In addition, the report indicated that clinical incompetence was the leading cause of maternal mortality. This included inadequate monitoring of women in labor, prolonged abnormal observations without staff action and a lack of obstetric emergency skills amongst staff (Riches, 2023). The objective of this paper is to model and forecast MMR for Malawi using a machine learning technique. The study findings will guide policy making, planning and allocation of resources to the maternal and child health program so as to further reduce maternal mortality across the country.

LITERATURE REVIEW

Author(s)	Objective(s)	Methodology	Key finding(s)
Collins et al. (2025)	To develop an individual-based model of maternal and perinatal health and healthcare in Malawi, situated in a 'whole-health system, all-disease' framework	Researchers modelled sixteen scenarios estimating the impact of current and improved coverage and quality of antenatal, intrapartum, and postnatal services from 2023 to 2030	Whilst current service delivery is inferred to avert morbidity and mortality, the largest reductions in the stillbirth, maternal and neonatal mortality rates were observed when the use and quality of all services was maximized concurrently (a 10%, 52% and 57% reduction respectively)
Gondwe et al. (2025)	To undertake a national maternal health prioritization exercise involving key stakeholders to enhance delivery of maternal care in Malawi.	Qualitative approach	Achieving national maternal health targets demands prioritizing respectful maternity care, accessible information, robust data management/information, and skilled birth attendants, all of which empower staff and clients to drive positive changes
Merriel et al. (2021)	to identify ways in which working lives of maternity healthcare workers could be enhanced to improve clinical care in Malawi	-conducted a 1-year ethnographic study of 3 district-level hospitals in Malawi	The Malawian system is under resourced with staff unable to provide high-quality care because of the lack of infrastructure and equipment. However, some processes hinder them on national and local level, for example staff rotations and poorly managed processes for labeling drugs.
Mgawadere et al. (2017)	to explore the relative contribution of each type of delay to maternal mortality in Malawi	151 maternal deaths were identified during a 12-month reproductive age mortality survey (RAMOS) conducted in Malawi; verbal autopsy and facility-based medical record reviews were conducted to obtain details about the circumstances surrounding each death. Using the three delays framework, data were analyzed for women who had; 1) died at a healthcare facility, 2) died at home but had previously accessed care and 3) died at home and had not accessed care	The majority of women do try to reach health services when an emergency occurs, but type 3 delays present a major problem
Bazile et al. (2015)	To demonstrate the short- and long-term impacts of maternal death on children, families, and the community in order to raise awareness of the true costs of maternal mortality and poor maternal health care in Neno, a rural and remote district in Malawi	Qualitative study	Maternal death exacerbated children's vulnerabilities to long-term health and social impacts related to nutrition, education, employment, early partnership, pregnancy, and caretaking. Impacts were particularly salient for female children who were often forced to take on the majority of the household responsibilities

Kumbani et al. (2012)	to determine perinatal mortality, to identify associated risk factors, and to determine causes of perinatal deaths at Chiradzulu District Hospital, Malawi	The study was designed as a cross-sectional study that prospectively reviewed records of 606 births at the health facility	The primary cause (75%) was birth asphyxia. Significant associations with perinatal death included: number of antenatal visits, most in one visit (29.4%); gestation ≤ 31 weeks (47%); prolonged second stage of labor (22%); premature babies with birth weight ≤ 1499 grams (61%); and severely asphyxiated babies (46%)
Kambala et al. (2011)	to identify and understand experiences, perceptions and needs of the community on maternal health service utilization	Qualitative study	The discussions revealed the following as barriers to maternal health service utilization: walking long distances to access health facilities, lack of midwives, lack of or insufficient items to be used during delivery, long stay and rude health personnel

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 Malawi.

Data Issues

This study is based on annual MMR in Malawi 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	M
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	0.008468
MSE	123.113912
MAE	8.202420

Residual Analysis for the Applied Model

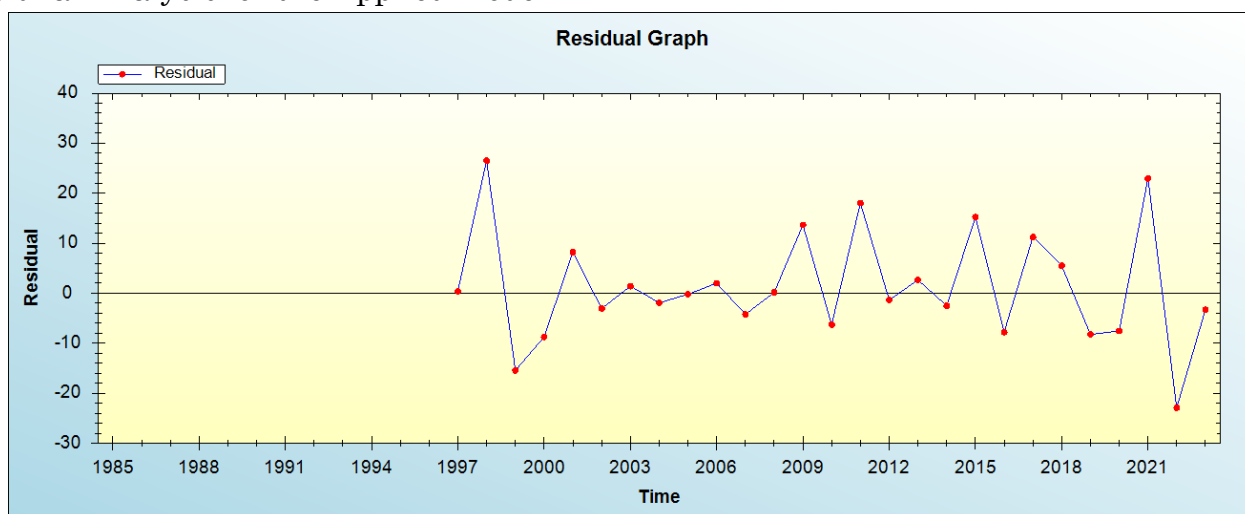


Figure 1: Residual analysis

In-sample Forecast for M

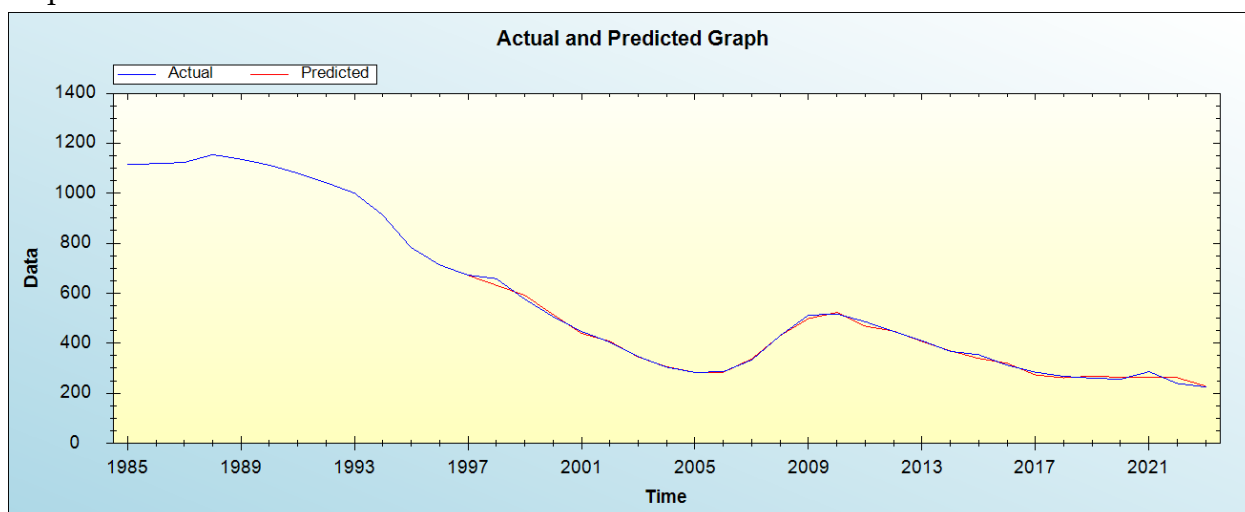


Figure 2: In-sample forecast for the M series

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

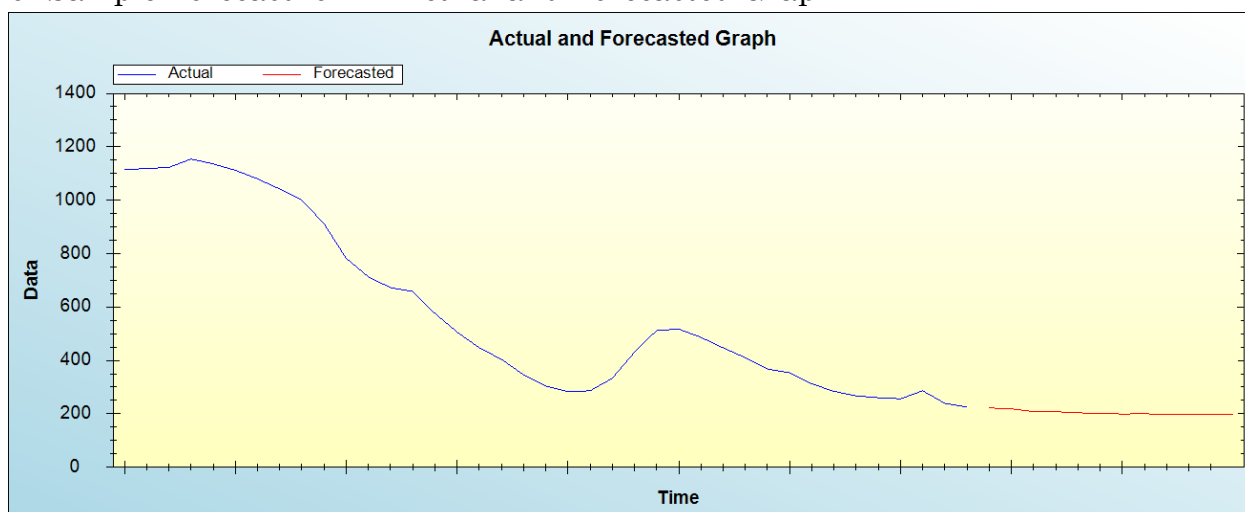


Figure 3: Out-of-sample forecast for M: actual and forecasted graph

Out-of-Sample Forecast for M: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	221.8900
2025	218.2122
2026	207.9464
2027	207.5636
2028	203.8938
2029	200.4701
2030	199.1589
2031	199.8987
2032	198.6634
2033	198.1151
2034	196.9788
2035	196.4857

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 will remain very high throughout the out of sample period.

RECOMMENDATIONS & CONCLUSION

Malawi's MMR is still very high despite a significant increase in antenatal care attendance and skilled birth attendance at 97%. This high maternal mortality rate indicates that there are existing gaps and deficiencies in the continuum of care. At health care facility level, clinical incompetence is the leading cause of maternal deaths. This is characterized by inadequate monitoring of women in labor, prolonged abnormal observations without staff action and a lack of obstetric emergency skills amongst staff. In this study we apply the multilayer perceptron to forecast MMR for Malawi and findings indicate that MMR is anticipated to remain very high in the out of sample period. Therefore, we encourage health 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) conduct routine quality improvement activities across the country (4) ensure availability of adequate medical supplies and medical staff in all medical facilities and (5) create 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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