

FORECASTING ANNUAL MATERNAL MORTALITY RATE FOR MOROCCO USING THE MULTILAYER PERCEPTRON

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ABSTRACT

This research article employs annual time series data on MMR for Morocco 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 decline from around 73.5 in 2024 to about 67 deaths per 100 000 live births throughout the out of sample period. Therefore, we encourage the government to address local causes of preventable maternal mortality and direct resources towards the implementation of quality improvement initiatives.

Keywords: ANN, Forecasting, Maternal Mortality Ratio

INTRODUCTION

Maternal mortality is defined as the demise of a woman during pregnancy, childbirth or the post-partum period, from any cause related to or aggravated by the pregnancy or its management (Patwardhan et al. 2016). The maternal mortality ratio (MMR) is an indicator of healthcare quality, whose reduction is a major global challenge (MacDorman et al. 2018). It is defined as the number of maternal deaths during a given period per 100,000 live births (LB) during the same period. According to WHO, obstetric hemorrhage, hypertensive disorders and sepsis are major causes of maternal death worldwide (Say et al. 2014). Numerous factors increase the risk of maternal death, such as maternal age over 35 years. Over the recent decades, the MMR has declined globally, although there were disparities between countries depending on their income levels and maternal health policies (Ruiz-Cantero et al. 2019). Maternal mortality rate is low in first world country and is usually due to pre-existing non-communicable diseases (NCDs). While it is more common in developing countries, due to lack of access to skilled maternal healthcare (Kulczycki et al. 2017). Pregnancy related mortality was also found higher in rural than in urban areas even in high-income countries such as United States (Merkt et al. 2021). Maternal mortality in Morocco decreased over the period 2000-2020 from 244 to 72.6 deaths per 100,000 live births (WHO, 2023). This paper aims to model and forecast MMR for Morocco using a machine learning technique. The study findings are expected to guide policy making, planning and allocation of resources to the health sector.

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
Gebili et al. (2025)	to identify the characteristics and predictors of coronavirus disease (COVID-19) related maternal deaths in 2020 and 2021, and to assess maternal mortality ratio (MMR) from 2018 to 2021 in Egypt	A record-based cross-sectional analytical study was conducted in four randomly selected governorates: Kafr El-Sheikh, El-Behira, (Lower Egypt) and Assiut, and Fayoum (Upper Egypt)	-Direct causes, including postpartum hemorrhage, preeclampsia, and embolism, accounted for 47.5% of deaths. As one of indirect causes of deaths, COVID-19 was diagnosed in 25.3%, it was the sole cause in 75.0% of them -The overall MMR increased between 2018 and 2021 with significant increases observed in Fayoum (from 39.25 to 71.65; $p < 0.001$) and Kafr El-Sheikh (from 36.44 to 56.6; $p = 0.032$) -residing in lower Egypt and hospital referral refusals were predictors of COVID19 related maternal mortality
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
Oumbarek et al. (2024)	to compare trends of in-hospital maternal mortality in southern Morocco before and after the COVID-19 pandemic emerged in the Kingdom in March 2020	conducted a retrospective study of a time series of hospital maternal deaths from January 2016 to December 2022. Data were collected from maternal death registers and monthly reports from maternity departments of six public hospitals in Souss Massa region (one regional and five provincial hospitals)	In-hospital MMR increased in public hospitals of the Souss Massa region during the COVID-19 pandemic, particularly in the third quarter of 2021
Salihi et al. (2023)	to identify the characteristics of pregnancy-related deaths of Moroccan expectant mothers, determine the prevalence of	Conducted a retrospective descriptive study on maternal suicides in the Moroccan population	although there is a dearth of high-quality information about suicide in Morocco, it is

	perinatal suicide, and evaluate its risk factors	between the ages of 14 and 45. The suicides happened between the time of pregnancy and the first two years after delivery. The study covered a ten-year period and focused on the death registry of Casablanca's forensic pathology department (January 2003-December 2013)	undeniably a serious and expanding public health issue
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
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
Mahmouda & Omar (2018)	to assess the awareness and perceptions of women about maternal mortality issues in rural areas in both Assiut and Fayoum Governorates		There are no statistical significance differences between both groups in rural communities regarding the levels of awareness about maternal mortality
Bashour et al. (2015)	report findings from the formative stage of a World Health Organization (WHO) funded implementation research study that was undertaken to collect primary data at the facility level on the prevalence, characteristics, and management of maternal near-miss cases in four major public referral hospitals- one each in Egypt, Lebanon, Palestine and Syria	conducted a cross-sectional study of maternal near-miss cases in the four contexts beginning in 2011, where we collected data on severe maternal morbidity in the four study hospitals, using the WHO form (Individual Form HRP A65661)	Overall, hemorrhage-related complications were the most frequent conditions among maternal near-miss cases across the four study hospitals. In all hospitals, coagulation dysfunctions (76.1 %) were the most prevalent dysfunction among maternal near-miss cases, followed by cardiovascular dysfunctions. The coverage of key evidence-based interventions among women experiencing a near-miss was either universal or very high in the study hospitals

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 Morocco.

Data Issues

This study is based on annual MMR in Morocco 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	R
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	0.001109
MSE	11.409428
MAE	1.956500

Residual Analysis for the Applied Model

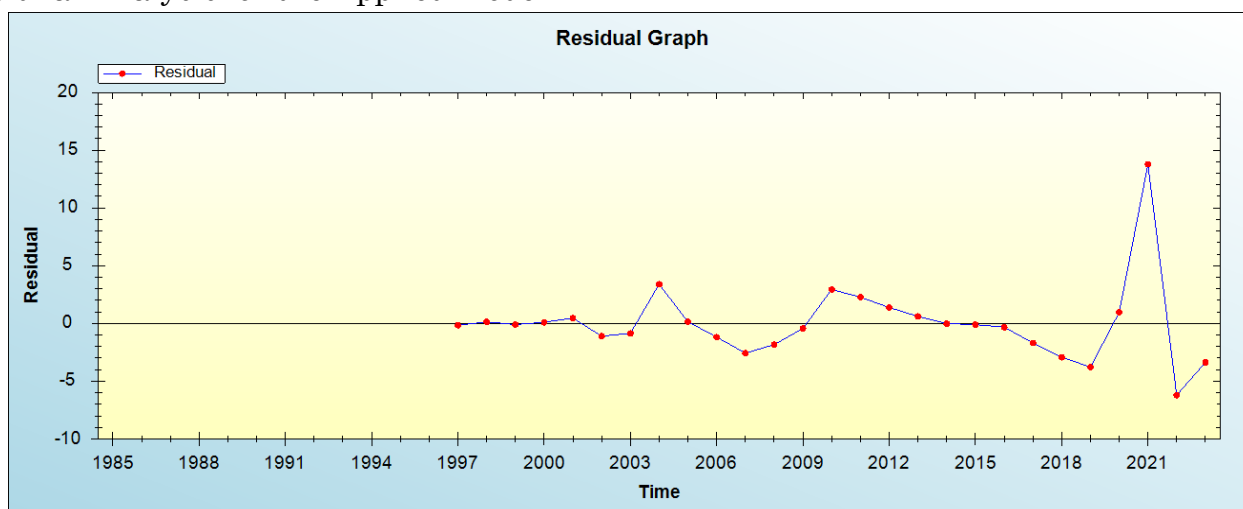


Figure 1: Residual analysis

In-sample Forecast for R

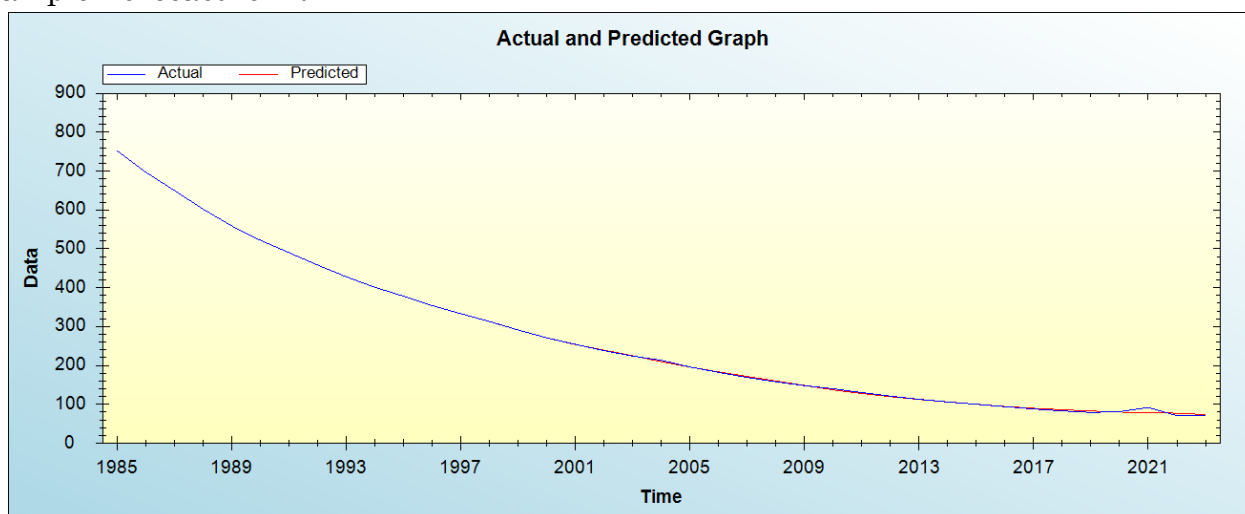


Figure 2: In-sample forecast for the R series

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

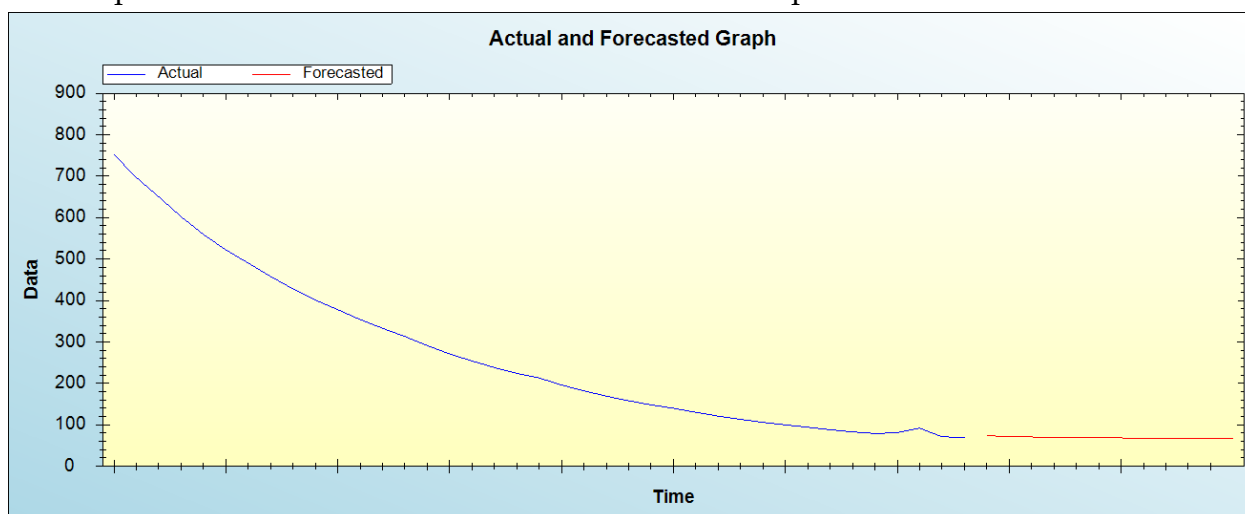


Figure 3: Out-of-sample forecast for R: actual and forecasted graph

Out-of-Sample Forecast for R: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	73.4746
2025	72.2952
2026	70.6787
2027	69.2123
2028	68.6589
2029	69.0702
2030	68.3702
2031	68.2568
2032	68.1813
2033	66.8619
2034	66.9507
2035	67.0622

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 decline slightly from around 73.5 in 2024 to about 67 deaths per 100 000 live births by 2035.

RECOMMENDATIONS & CONCLUSION

Morocco has reported significant decline of maternal mortality over the previous decades highlighting huge investments in the health sector and others sectors of the economy. However, current MMR although relatively low reflects some deficiencies in the continuum of care. This paper applied a machine learning approach to model and forecast MMR and results indicate that MMR will decline slightly from around 73.5 in 2024 to about 67 deaths per 100 000 live births by 2035. Therefore, we implore authorities to attend to main drivers of maternal mortality and channel resources towards implementation of quality improvement strategies.

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