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Projecting Future Trends of Under Five Mortality Rate for Rwanda Using a Machine Learning Algorithm

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***Abstract* - This study uses annual time series data on under five mortality rate for Rwanda from 1960 to 2020 to predict future trends of under-five mortality rate over the period 2021 to 2030. Residuals and forecast evaluation criteria indicate that the applied ANN (12, 12, 1) model is stable in forecasting U5MR. ANN model projections revealed that the annualU5MR will hover around 42 deaths per 1000 live births throughout the out of sample period. Therefore, we implore the Rwandan government to focus on solving all the pertinent issues affecting under five children especially in the rural areas.**

Keywords: ANN, Forecasting, U5MR.

I. INTRODUCTION

Rwanda has made significant progress in curbing child mortality as evidenced by a decline in under 5 and neonatal deaths (World Bank, 2019). During the period 2005-2015 neonatal mortality declined from 37 deaths per 1000 live births to 20 per 1000 live births and under 5 mortality declined from 152 to 50 deaths per 1000 live births (Rwanda, 2015). Several government strategies have yielded positive results however more needs to be done (Musafili *et al*. 2015). In line with sustainable development goals (SDGs), the government adopted several measures such as childhood immunizations, Vitamin A supplementation and strengthening essential newborn care. This study applies the multilayer neural network approach and the findings are expected to help public health authorities to make informed decisions & policies and facilitate allocation of resources towards maternal and child health (MNCH) programs in the country. Furthermore, forecast results will assist to track the country's progress towards achieving the set sustainable development goal 3 target 3.2 by 2030 which aims to substantially reduce under five mortality rate to as low as 25 per 1000 live births (WHO, 2019; UNICEF, 2019; UNICEF, 2018).

II. LITERATURE REVIEW

Gage & Bauhoff (2020) assessed the impact of PBF on early neonatal health outcomes and associated health care utilization and quality in Burundi, Lesotho, Senegal, Zambia and Zimbabwe. Authors utilized data from Demographic and Health Surveys and Multiple Indicator Cluster Surveys and applied difference-in-differences analysis to estimate the effect of PBF projects supported by the World Bank on early neonatal mortality and low birth weight and concluded that PBF had no impact on early neonatal health outcomes in the five African countries studied and had limited and variable effects on the utilization and quality of neonatal health care.Another study by Nyoni & Nyoni, 2020 applied the Box-Jenkins ARIMA methodology to forecast neonatal deaths in Zimbabwe using annual time series data on neonatal deaths in Zimbabwe from 1966 to 2018.The ARIMA (8, 2, 0) was found to be the optimal model. The study findings revealed that the numbers of neonatal deaths per year would decline sharply over the next 25 years. In a 2018 descriptive study, Merabet *et al* described neonatal deaths and identified their risk factors at the Al Hoceima Provincial Hospital. The study findings suggested that neonatal mortality in the Al Hoceima hospital remains high and is mainly related to the course of pregnancy and childbirth as well as the characteristics of the newborn at birth. A matched case-control study using verbal social autopsy was conducted by Gupta *et al*. (2018) to investigate the causes and predictors of childhood mortality in Rwanda. Authors utilized conditional logistic regression to identify clinical, family, and household risk factors for death. It was found out that there was a large proportion of remaining deaths occur at home, with home deliveries still representing a significant risk factor for neonatal death. The major causes of death at a population level remain largely avoidable communicable diseases. Khurmi *et al*. (2017)reviewed evidence-based interventions and coverage levels already implemented in Rwanda and identified key issues and bottlenecks in service delivery and uptake of services by community/beneficiaries. This study utilized mixed method research including qualitative and quantitative analyses of various maternal and newborn health programs implemented in the country. The findings of the study indicated that policies, protocols, various guidelines and tools for monitoring are already in place however, implementation of these remains a challenge.

III. METHODOLOGY

The Artificial Neural Network (ANN) approach, which is flexible and capable of nonlinear modeling; will be applied in this study. The ANN is a data processing system consisting of a large number of highly interconnected processing elements in

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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 under five mortality rate for Rwanda.

Data Issues

This study is based on annual under five mortality rate in Rwanda for the period 1960 – 2020. The out-of-sample forecast covers the period 2021– 2030. All the data employed in this research paper was gathered from the World Bank online database.

IV. FINDINGS OF THE STUDY

ANN Model Summary

Table 1: ANN model summary

Variable	R
Observations	49 (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	0.024374
MSE	21.288272
MAE	2.458962

Residual Analysis for the Applied Model

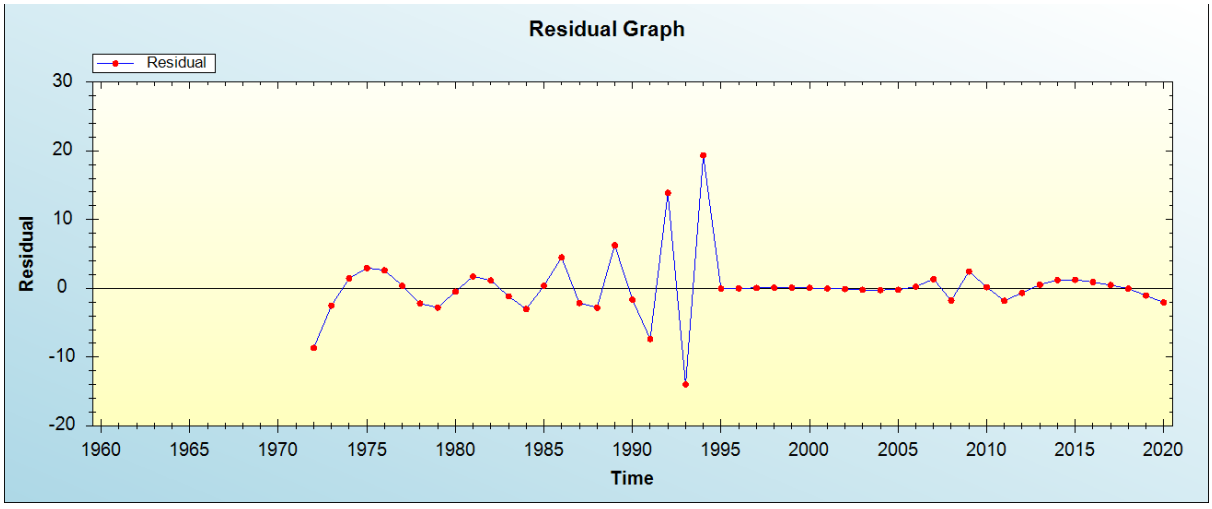

Figure 1: Residual analysis

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In-sample Forecast for R

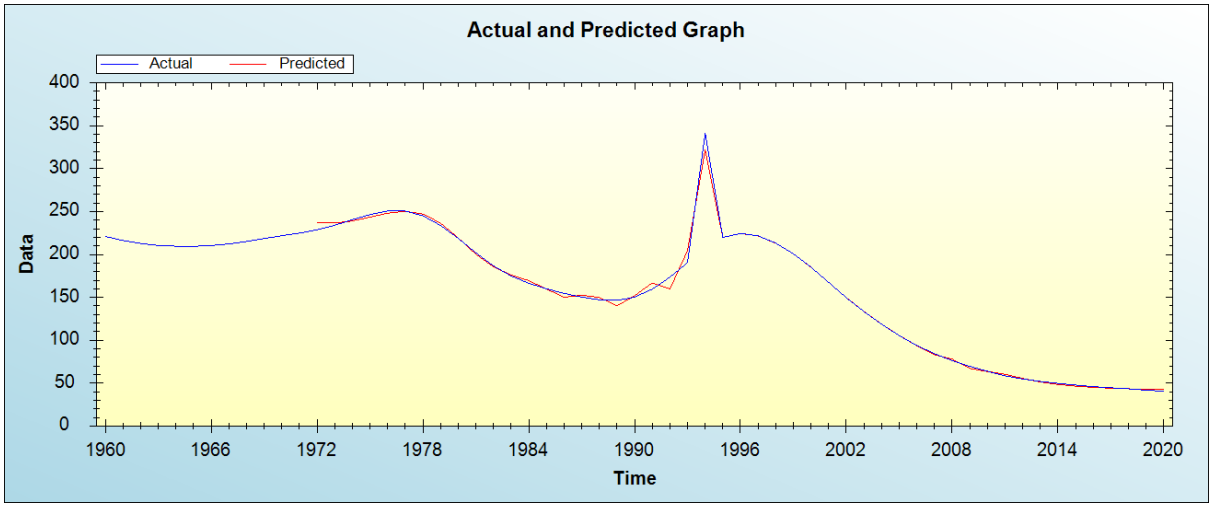

Figure 2: In-sample forecast for the R series

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

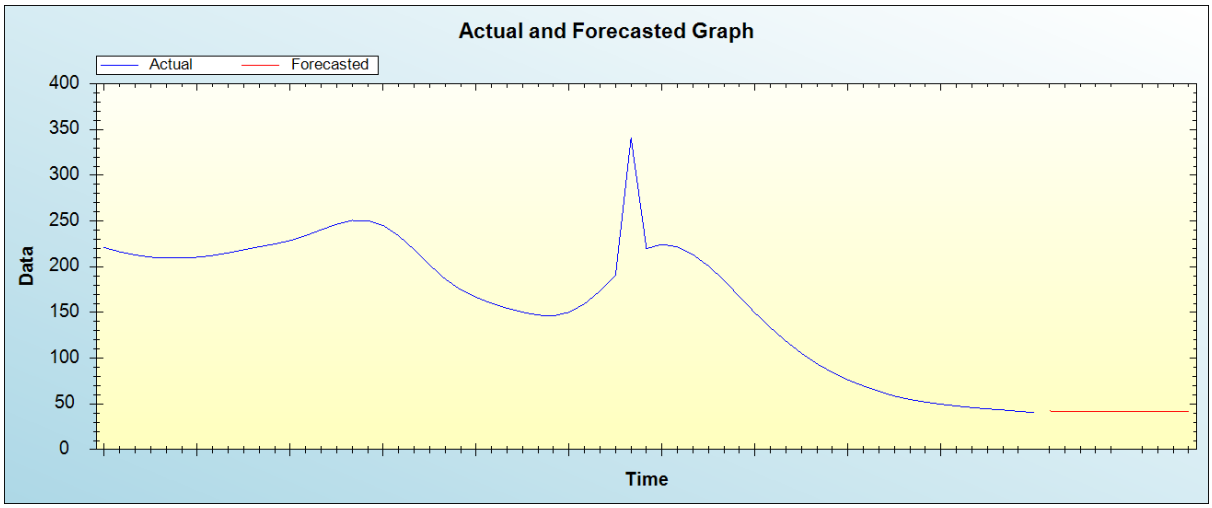

Figure 3: Out-of-sample forecast for R: actual and forecasted graph

Out-of-Sample Forecast for R: Forecasts only

Table 2: Tabulated out-of-sample forecasts

2021	42.2842
2022	42.1175
2023	41.9568
2024	41.8519
2025	41.7999
2026	41.7333
2027	41.6887
2028	41.6454
2029	41.6354
2030	41.6541

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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 U5MR will hover around 42 deaths per 1000 live births throughout the out of sample period.

V. POLICY IMPLICATION & CONCLUSION

Despite having numerous challenges, the Rwandan government has done very well in implementing strategies that improve child survival such as early pediatric antiretroviral drug therapy initiation, childhood immunizations, Vitamin A supplementation and integrated management of childhood illnesses. This study applies the ANN model to predict future trends of under-five mortality rate in Rwanda and forecast results revealed thatthe annual U5MR will hover around 42 deaths per 1000 live births throughout the out of sample period. Therefore, the Rwandan government should focus on solving all the issues affecting under five children especially in the rural areas.

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