Forecasting Total Fertility Rate in Mali Using a Machine Learning Technique

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Abstract - **In this research article, the ANN approach was applied to analyze TFR in Mali. The employed data covers the period 1960-2018 and the out-of-sample period ranges over the period 2019-2030. The residuals and forecast evaluation criteria (Error, MSE and MAE) of the applied model indicate that the model is stable in forecasting TFR in Mali. The results of the study indicate that annual total fertility rates in Mali are likely to rise slightly over the out-of-sample period. Therefore, the Mali government is encouraged to concentrate its effort on addressing barriers to accessing sexual and reproductive health (SRH) services among adolescents and young adults, and prioritize women empowerment.**

Keywords: ANN, Forecasting, Total fertility rate (TFR).

I. INTRODUCTION

The total fertility rate of a population is the average number of children that would be born to a woman throughout her lifetime if she were to pass through her reproductive years at the current age specific rates. It is also defined as the summation of the age specific rates multiplied by 5 (Demena, 2005). TFR is an important standard measure of fertility. Mali has a total population size of 22.25 million and 43% of the population is urban. Mali's fertility rates have been decreasing over the years from 7.2 births per woman in 1995 to 5.9 births per woman in 2020 (Worldometer, 2020). Infant and under five mortality rates have been falling over the years as well with Infant mortality rate dropping from 241.92 infant deaths per 1000 live births in 1950 to 57.2 infant deaths per 1000 live births in 2020.Under five mortality fell from 427.48 deaths per 1000 live births in 1950 to 9.93 deaths per 1000 live births in 2020 (Worldometer, 2020). These figures indicate that there has been significant progress made in reducing child mortality in the country. There are limited studies in the region that have focused on examining fertility and fertility trends. Wado et al (2021) did a study to determine inequalities in physical or sexual IPV (intimate partner violence) against AYW and beliefs about gender based violence (GBV) in sub-Saharan Africa (SSA). The authors used data from the most recent Demographic and Health Surveys (DHS) conducted in 27 countries in SSA. The findings showed that IPV is pervasive among AYW, with substantial variation across and within countries reflecting the role of contextual and structural factors in shaping the vulnerability to IPV. Genus (2020) examined the determinants of trends wanted and unwanted fertility in SSA using fixed-effects regressions of country-level data. Data came from 103 DHS surveys in 25 countries in SSA with at least two DHS surveys between 1989 and 2019. The study revealed that Women's education and family planning programs are found to be the dominant determinants of fertility decline and their effects operate by reducing both wanted and unwanted fertility. Based on an explorative qualitative study conducted by Dessalegn (2020) in five districts in Ethiopia. Sixteen key informants and eight focus group discussions were conducted among adult women and men of young adolescents and youth. The study revealed that younger and older women are the most disadvantaged groups of the society.

Based on a cross-sectional study, Renzaho et al (2017) examined factors associated with comprehensive categories of sexual and reproductive health, including sexual behaviors; sexual education and access to contraceptive services; family planning; prevention of STDs; sexual consent as a right; gender based violence; as well as HIV testing, counselling, disclosure and support. The study indicated that there is need to address barriers and ensure a comprehensive and harmonized sexual and reproductive health system that is youth friendly and takes into account local socio-cultural issues.

Tunçalp et al (2015) carried out a study to understand the association between levels of conflict and displacement and the availability of SRH services in post-conflict Mali. A national assessment was conducted between April and May 2013 employing Health Systems Availability Mapping System (HeRAMS). Data from 1581 primary care facilities were analyzed, focusing on SRH services. Descriptive analyses and multivariable logistic regression models were used to examine the availability of SRH services by different levels of conflict and displacement. The study concluded that those living in conflict areas, and many of those who are internally displaced, have poor access to essential SRH interventions.

The aim of the study is forecast TFR in Mali using a machine learning approach. The results of the study are expected to reveal likely future trends of TFR in Mali to facilitate planning and resource mobilization for health, education and employment creation.

II. 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 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 total fertility rates in Mali.

Data Issues

This study is based on annual total fertility rate (births per woman)in Mali for the period 1960 – 2018.The out-of-sample forecast covers the period 2019 – 2030.All the data employed in this research paper was gathered from the World Bank online database.

III. FINDINGS OF THE STUDY

ANN Model Summary

Table 1: ANN model summary

Variable	M
Observations	47 (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	0.138778
MSE	0.010046
MAE	0.075403

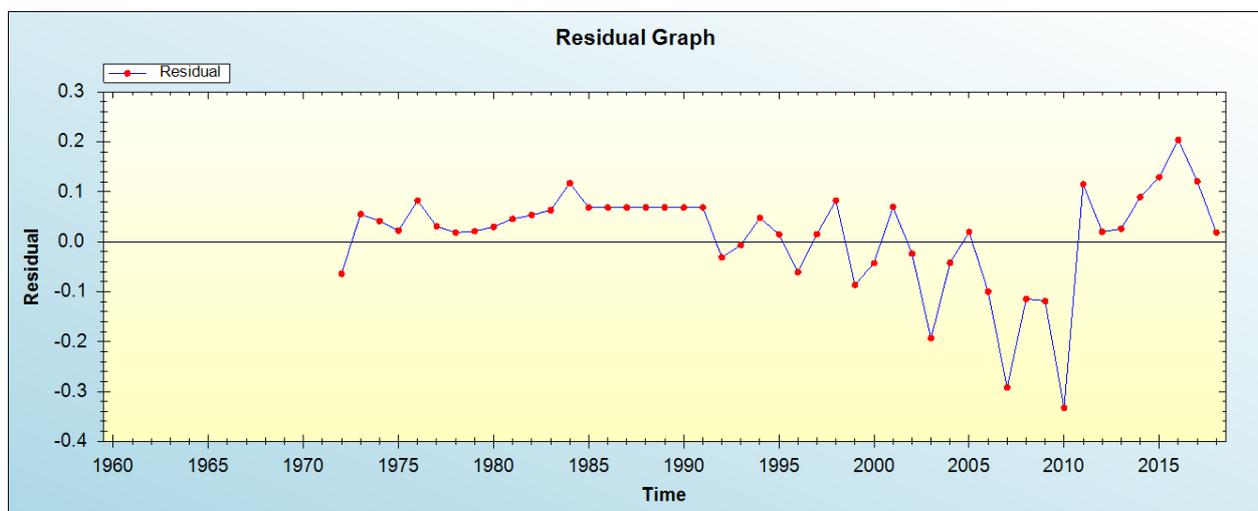*Residual Analysis for the Applied Model*

Figure 1: Residual analysis

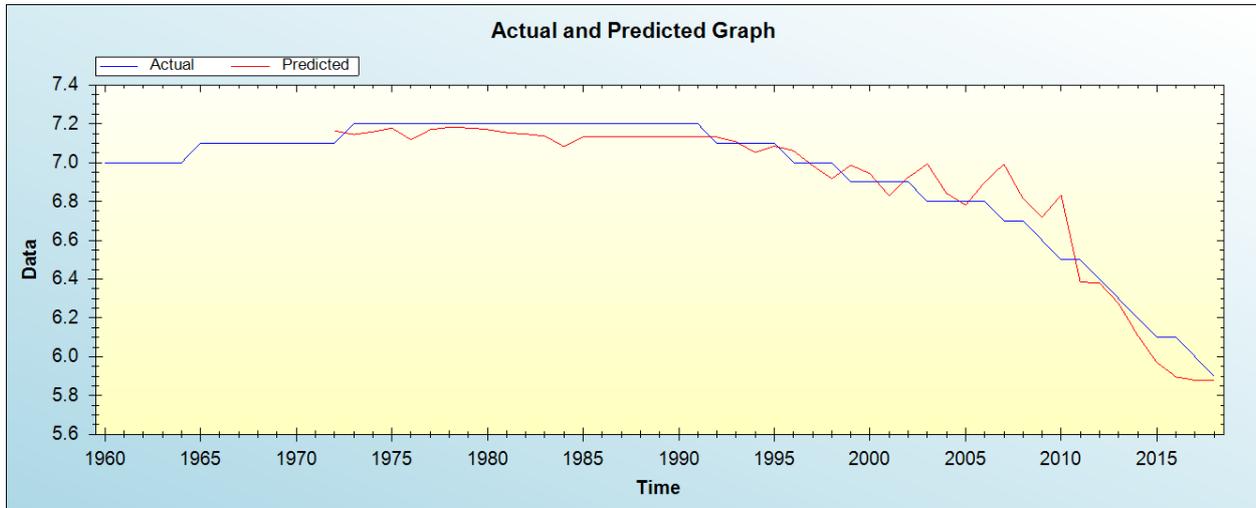*In-sample Forecast for M*

Figure 2: In-sample forecast for the M series

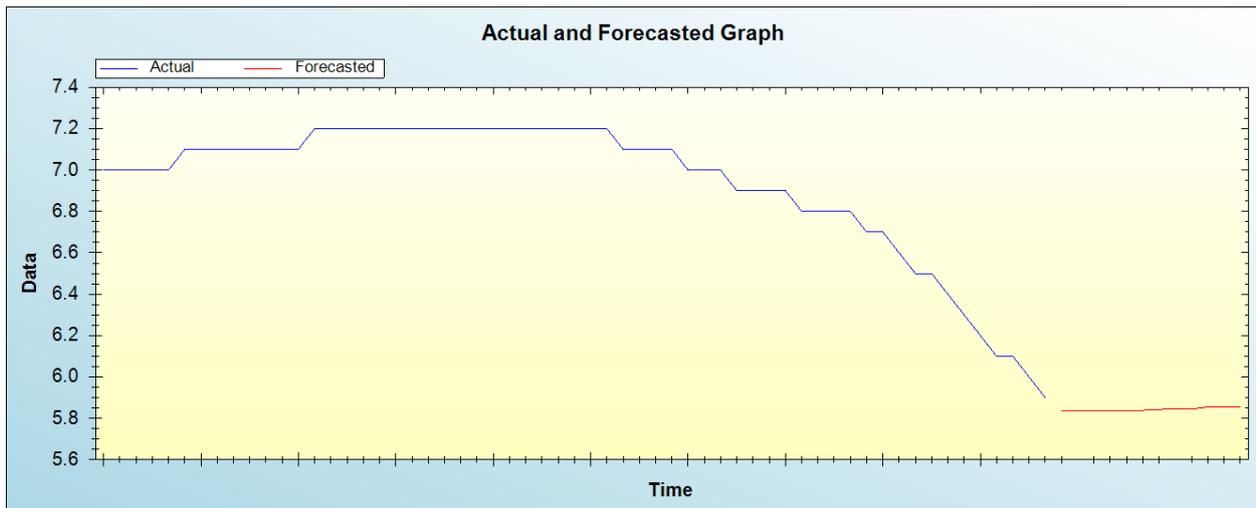*Out-of-Sample Forecast for M: Actual and Forecasted Graph*

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	Forecasts
2019	5.8381
2020	5.8387
2021	5.8372
2022	5.8347
2023	5.8377
2024	5.8391
2025	5.8433
2026	5.8479
2027	5.8449
2028	5.8555
2029	5.8557
2030	5.8532

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 total fertility rates in Mali are likely to rise slightly over the out-of-sample period.

IV. CONCLUSION & RECOMMENDATIONS

Mali has high maternal, infant and child mortality rates. The country's TFR has been declining over the years but still remains high due to high numbers of teenage or adolescent pregnancies. In this study, we proposed a machine learning technique to forecast TFR in Mali. The results of the study indicated that annual total fertility rates in Mali are likely to rise slightly over the out-of-sample period. Therefore we encourage the government of Mali to concentrate its effort on addressing barriers to accessing sexual and reproductive health (SRH) services among adolescents and youths, and prioritize women empowerment.

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