Modeling and Forecasting Annual TB Incidence in Mozambique: A Stern Warning from Artificial Neural Networks

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Abstract - **Mozambique is a high TB burden country which is suffering from civil war and natural disasters (mainly floods). It is struggling to control the TB epidemic as it has seen the rise in TB incidence over the period 2000-2018.In this research article, the ANN approach was applied to analyze TB incidence in Mozambique. The employed annual data covers the period 2000-2018 and the out-of-sample period ranges over the period 2019-2023. The residuals and forecast evaluation criteria (Error, MSE and MAE) of the applied model indicate that the model is stable in forecasting TB incidence in the Republic of Mozambique. The results of the study indicate that TB incidence will remain very high over the period 2019-2023. The government and its HIV/TB funding partners should allocate more financial resources towards HIV/TB prevention and control programs. The health ministry in Mozambique should intensify TB surveillance and control programs among other robust measures in order to significantly reduce TB incidence in the country.**

Keywords: ANN, Forecasting, TB incidence.

I. INTRODUCTION

Tuberculosis (TB) remains an important public health problem Worldwide (WHO, 2018) and Mozambique is not an exception. The TB burden is being worsened by the emergence of Multidrug-resistant TB ,extensively drug resistant TB and the presence of TB-HIV co-infection(WHO, 2018; Anselmo, 2019). The incidence of TB in Mozambique in 2014 was 551 cases per 100 000 population and is among the highest in the World (Saifodine et al, 2014). The country had 159 000 active TB cases in 2016 and the HIV prevalence is high with 45% of TB patients being infected with HIV virus (WHO, 2017). It is important to mention that Mozambican Health care workers have high rates of active TB and latent TB infection which is a typical feature of healthcare workers in low and middle income countries (Apriani et al,2019; Josh et al, 2006; Sharma et al, 2018; Belo & Naidoo, 2017; Adam et al, 2015; MISAU, 2010; Brouwer et al, 2015). TB is caused by mycobacterium tuberculosis and the disease primarily affects the lungs. The bacilli are transmitted via air droplets when an infected person coughs or sneezes. The classical symptoms of the disease are fever, productive cough for more than 2weeks, hemoptysis, shortness of the breath and weight loss. The clinical diagnosis involves history taking and clinical assessment together with laboratory confirmation. Sputum samples from suspected TB cases are sent for Gene Xpert analysis and microscopy, culture and sensitivity testing. The chest x-ray is the main radiological test for pulmonary TB. Ultrasonography and CT scan play an important role in the detection of extra pulmonary TB. It is critical that all baseline investigations in done when managing hospitalized patients particularly TB/HIV co-infected patients on antiretroviral therapy. All TB patients must be screened for HIV and vice versa. TB screening of all HIV positive patients on antiretroviral therapy is important in order to reduce morbidity and mortality due to TB and hence improve clinical outcomes. All ART patients who test negative for TB and have no contraindications are commenced on isoniazid preventive therapy. There are few empirical TB studies in Mozambique. Graves et al (2019) did a cross-sectional study to investigate the risk factors for TB in a Quaternary hospital in Mozambique. The researchers applied a multivariable logistic regression and their study concluded that there is a high prevalence of TB infected health workers in Maputo central hospital. The surgery department was the most affected suggesting occupational risk. Isoniazid preventive therapy initiation was high and just over half completed therapy. Ivanova et al (2020) conducted a study to perform lung function tests in order to create new Mozambican prediction equations for comparison with the Global Lung Initiative (GLI) and the South African equations. The research revealed that the predicted values for Forced Vital Capacity (FVC), Forced expiratory Volume 1(FEV1) and FEV1/FVC ratio based on Mozambican equations were lower than the South African and the GLI based predictions .Varela (2015) carried out a retrospective population based analysis in Manhica district to estimate the pediatric TB case detection rate by comparing the routine TB incidence rate in children aged less than 3years reported in the district between 2006 and 2010 with the incidence in

the study area computed during the prospective study(ITACA study: determination of the minimum incidence rate of TB in infants and children in the Manhica district, Mozambique ,October 2011-October 2012). The findings of the study showed that the estimated TB case detection rate in children less 3years in Manhica was 40.8% which is in line with low case detection rate for Mozambique reported by WHO. In this piece of work, the researchers applied the artificial neural network ANN (9,12,1) model to forecast the annual TB incidence in Mozambique. The results of the study will help the government to understand the future trends of TB in Mozambique, thus facilitating planning and initiating an early response to the TB epidemic.

II. METHOD

The Artificial Neural Network (ANN), which we will empirically apply in this paper; is a data processing system consisting of a l a r g e n u m b e r of simple and highly interconnected processing elements resembling a biological neural system. It has the capability of learning from an experimental or real data set to describe the nonlinear and interaction effects with great accuracy. ANN-based curve fitting technique is one of the extensively applied artificial intelligence methods that are used for forecasting and prediction purpose. It consists of basically three layers i.e., input layer, hidden layer, and output layer, the present work includes the number of years as input layer and the annual TB incidence in Mozambique as output data for the network. In this research paper, our ANN is based on the hyperbolic tangent function.

Data Issues

This study is based on TB incidences (reffered to as J series in this study) in Mozambique. The annual data covers the period 2000-2018 while the out-of-sample forecast covers the period 2019-2023. All the data employed in this research paper was gathered from the World Bank online database.

III. FINDINGS OF THE STUDY

DESCRIPTIVE STATISTICS

Table 1: Descriptive statistics

Mean	Median	Minimum	Maximum
536.26	540.00	513.00	551.00
Std. Dev.	C.V.	Skewness	Ex. kurtosis
14.944	0.027866	-0.31753	-1.5723
5% Perc.	95% Perc.	IQ range	Missing obs.
undefined	551.00	31.000	0

ANN MODEL SUMMARY FOR TB INCIDENCE (new cases per 100 000 population/year) IN MOZAMBIQUE

Table 2: ANN model summary

Variable	J
Observations	10 (After Adjusting Endpoints)
Neural Network Architecture:	
Input Layer Neurons	9
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	0.019861
MSE	0.175798
MAE	.0.686418

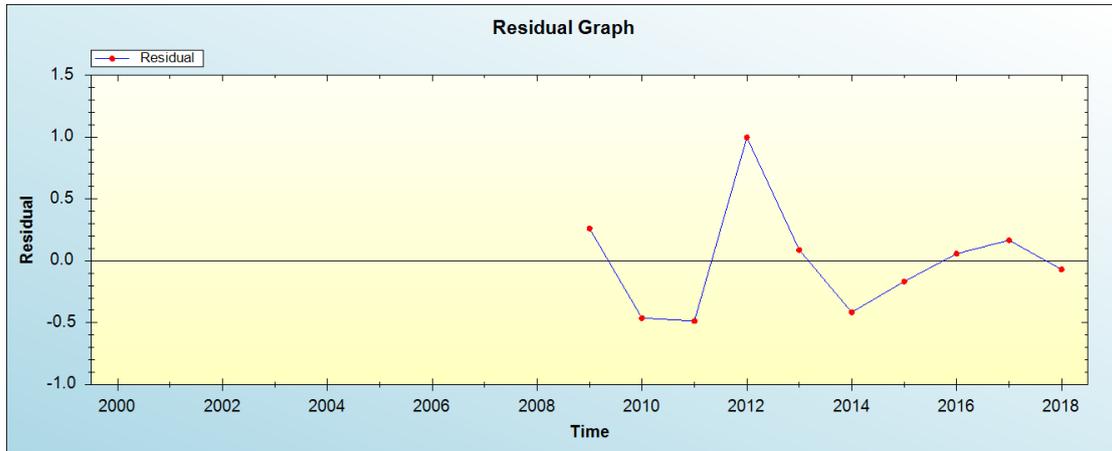*Residual Analysis for the ANN model*

Figure 1: Residual analysis
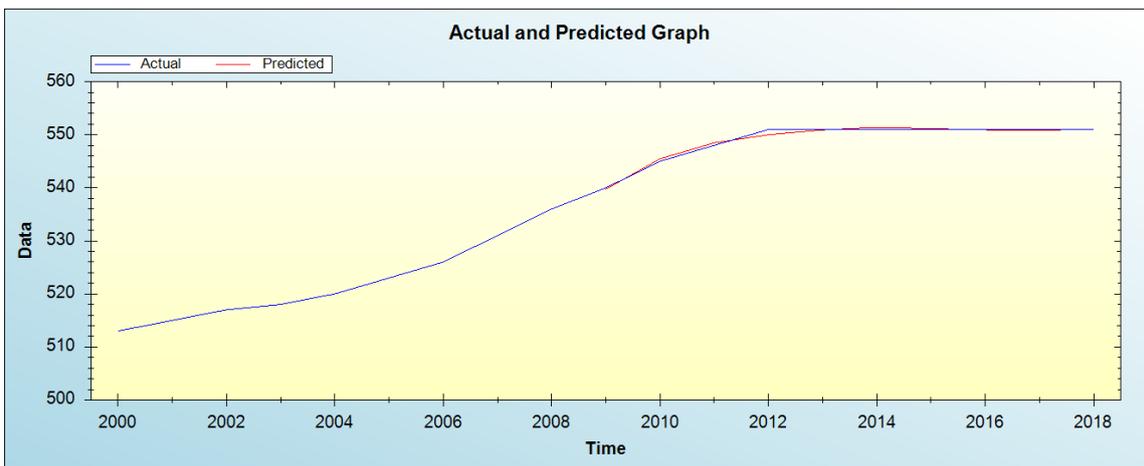
In-sample Forecast for J

Figure 2: In-sample forecast for the J series

Figure 2 shows the in-sample forecast for J series.

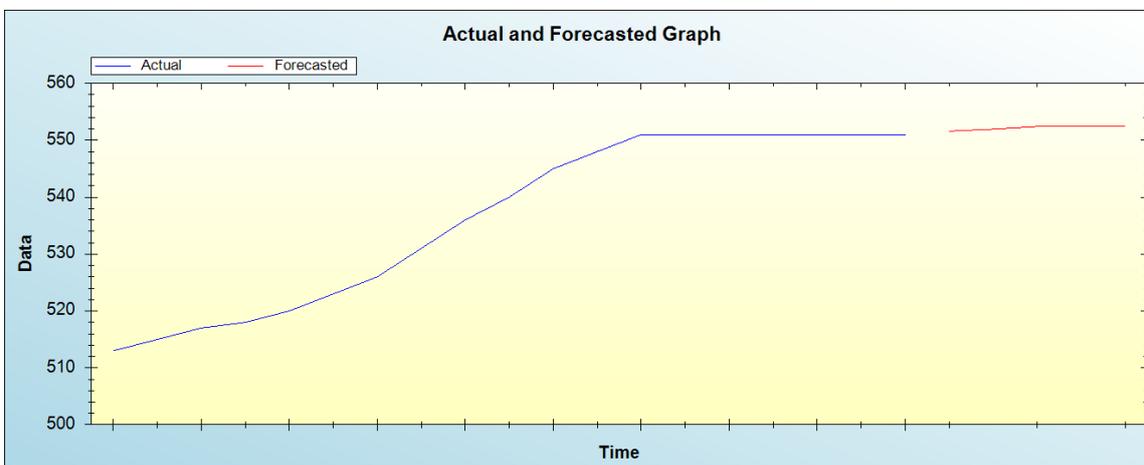*Out-of-Sample Forecast for J: Actual and Forecasted Graph*

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

Out-of-Sample Forecast for J: Forecasts only

Table 3: Tabulated out-of-sample forecasts

Year	Forecasts
2019	551.6047
2020	551.9644
2021	552.4202
2022	552.4805
2023	552.5034

Over the study period 2000-2018 the incidence of TB gradually increased until it reached a plateau point of 551 cases per 100 000 population/year in 2012 which persisted up to 2018 as shown by the graph. The minimum and maximum TB incidence was 513 and 551 cases per 100 000 population /year respectively with an average of 535 cases per 100 000 population per year. The applied data is negatively skewed with an excess kurtosis of -1.5723, meaning that the data is not normally distributed. The model evaluation criteria and the residuals indicate that the model is stable. In-sample forecasts suggest that the ANN (9,12,1) model simulates the data very well. The model predicts that over the out of sample period 2019-2023 the incidence will remain high at a constant level of around 552 cases per 100 000 population/year.

IV. CONCLUSION & RECOMMENDATIONS

Mozambique is struggling in the fight against the TB epidemic. The country has seen an increase in the incidence of TB over the period 2000-2018 and the model predicts that the incidence will remain high over the period 2019-2023.It seems the country is failing to effectively control the scourge. The country has a lot of work to do in order to reverse the upward trend in TB incidence. HIV/TB funders should channel more resources to Mozambique in order to effectively control the epidemic. In addition, the government should intensify TB surveillance and control programs amongst other measures.

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