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Forecasting TB Incidence in Oman Using the Multilayer Pecerptron Neural Network

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***Abstract* - In this research work, the ANN approach was applied to analyze TB incidence in Oman. 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 Oman. The results of the study indicate that TB incidence will remain low around 5.5 cases per 100 000 population/year over the period 2019-2023. The government is encouraged to continue on this commendable path by strengthening TB/HIV collaboration.**

Keywords: ANN, Forecasting, TB incidence.

I. INTRODUCTION

Tuberculosis (TB) is an infectious disease caused by the bacillus mycobacterium tuberculosis (Nyoni & Nyoni, 2019a & b). The disease primarily affects the lungs but can also affect other sites (extra pulmonary TB) (WHO, 2018).The risk of getting TB is increased with HIV infection ,malnutrition, Diabetes Mellitus ,smoking and drinking alcohol (WHO, 2003).Globally in 2010, 8.8 million incident TB cases were reported and WHO reported that TB is among the leading causes of mortality and disability (WHO, 2009).While TB is a curable condition, the TB treatment programs continue to face a myriad of challenges which include TB patients failing to complete TB treatment due to various reasons and emergence of multiple drug resistant TB (MDR-TB) (WHO, 2013). The World Health Organization recommends the Directly Observed Treatment Short course (DOTS) strategy in the treatment of TB. Under the strategy the patients are directly observed when taking their TB medications by healthcare workers, community health care workers and their caregivers. The purpose of the strategy is to ensure treatment adherence so as to improve treatment outcomes and minimize the development of drug resistant TB.TB treatment outcomes must be evaluated to assess program performance .The treatment success rate varies from country to country but generally it is around 83% worldwide (WHO, 2017).Studies done in Africa for example in Northern Ethiopia,the success rate was reported to be 89.2 % (Tola et al, 2019). The National TB program in Oman aims to detect and treat all forms of TB in order to reduce morbidity and mortality. The government is committed to the global TB strategies and associated targets as well as broader developmental goals set by the United Nations (UN). For the time period 2016-2035 these are the END TB strategy and Sustainable Development goals (WHO, 2018).The diagnosis of TB involves taking history ,physical examination and laboratory confirmatory tests. Laboratory tests to confirm the presence of TB infection include Gene-X pert machine, sputum smear microscopy and culture-based methods.

In this paper, the researchers applied the artificial neural network, the multilayer perceptron (MLP), ANN (9,12,1) model to predict the annual incidence of TB in Oman. The study findings will reveal the future trends of TB incidence in the country. This will facilitate planning and adequate allocation of resources to TB/HIV programs in the country.

II. LITERATURE REVIEW

Moosazadoh et al (2018) developed a SARIMA model to predict monthly TB incidence in Iran. Monthly data from April 2005 to March 2012 was analysed. The optimal model ,the SARIMA $(0,1,1)\ (0,1,1)_{12}$ predicted the incidence of smear positive TB for 2015 would be 9.8 per 100 000 people .Gashu et al (2018) analysed TB case notification rates in Ethiopia using the Winters' multiplicative method of the exponential smoothing .Notified TB cases for 2010-2016 was analysed using SPSS version 20.The study concluded that TB is a seasonal disease in Ethiopia with a peak in quarter four and a low in quarter two of the fiscal year. Nyoni & Nyoni (2019(a)) developed a SARIMA model to predict monthly TB notifications at Zengeza clinic in Zimbabwe .The study utilized the data covering the period January 2013 to December 2018The optimal model ,SARIMA $(2,0,2)(1,0,1)_{12}$ predicted that TB notifications would decline over the out of sample period .In a similar study Nyoni & Nyoni (2019b) modeled and predicted monthly TB notifications at Silobela District Hospital in Zimbabwe. The study utilized the

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monthly TB notification data covering the period January 2014 to December 2018.The optimal SARIMA (1,0,1) $(0,1,1)_{12}$ model projected that monthly TB notifications would decline over the out of sample period.

III. METHOD

The Artificial Neural Network (ANN), which we will apply; is a data processing system consisting of a large number 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 Oman as output data for the network. In this paper, our ANN is based on the hyperbolic tangent function.

Data Issues

This study is based on TB incidences (reffered to as O series in this study) in Oman. The annual data covers the period 2000-2018 while the out-of-sample forecast covers the period January 2020 to 2019-2023. All the data employed in this research paper was gathered from the World Bank online database.

IV. FINDINGS OF THE STUDY

DESCRIPTIVE STATISTICS

Table 1: Descriptive statistics

Mean	Median	Minimum	Maximum
11.963	12.000	5.9000	16.000
Std. Dev.	C.V.	Skewness	Ex. kurtosis
2.8879	0.24140	-0.63230	-0.54564
5% Perc.	95% Perc.	IQ range	Missing obs.
undefined	16.000	4.0000	0

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

Table 2: ANN model summary

Variable	O
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	0.055465
MSE	0.096858
MAE	0.280195

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Residual Analysis for the ANN model

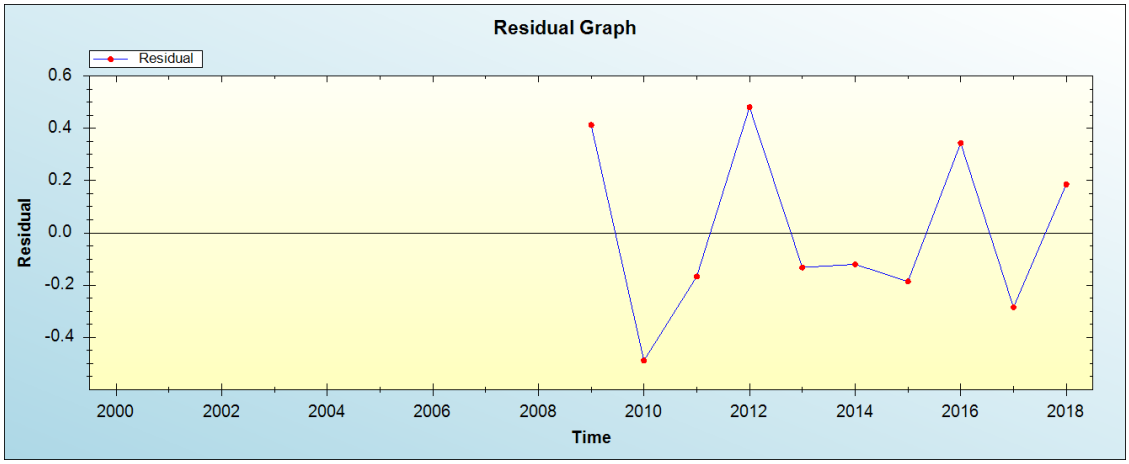

Figure 1: Residual analysis

In-sample Forecast for O

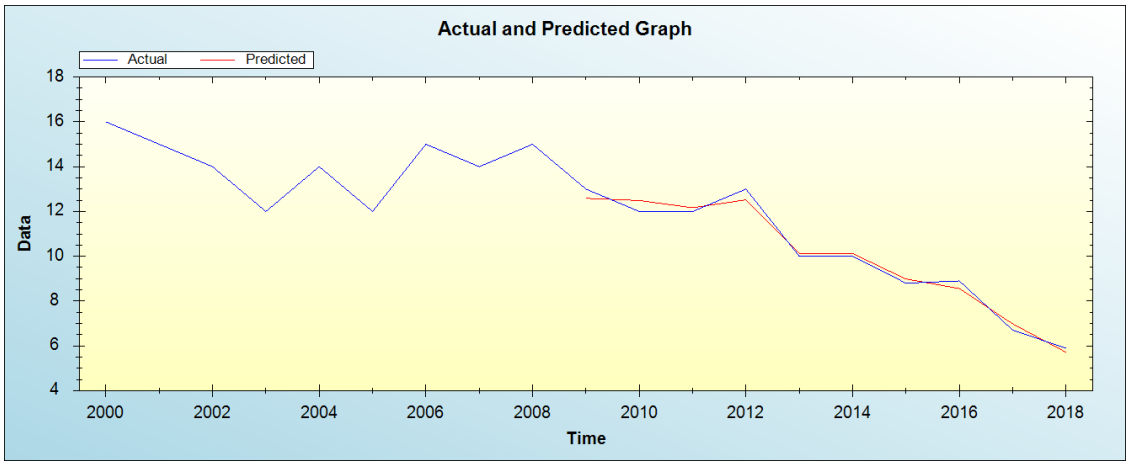

Figure 2: In-sample forecast for the O series

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

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

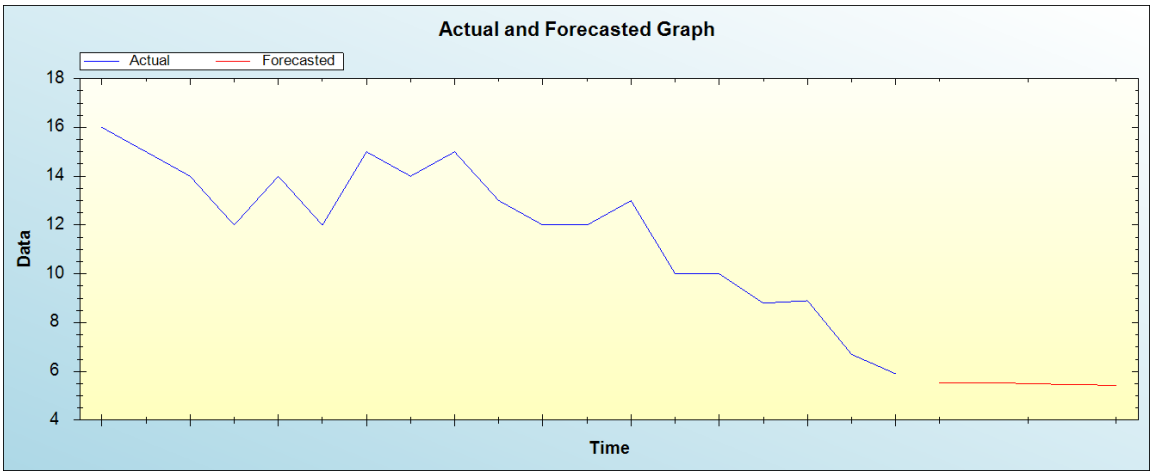

Figure 3: Out-of-sample forecast for O: actual and forecasted graph

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Out-of-Sample Forecast for O: Forecasts only

Table 3: Tabulated out-of-sample forecasts

Year	Forecasts
2019	5.5324
2020	5.5276
2021	5.5115
2022	5.4523
2023	5.4369

Over the study period 2000-2018 the incidence of TB gradually declined. The minimum and maximum TB incidence was 5.9 and 16.0 cases per 100 000 population/year with an average of 11.9 cases per 100 000 population/year. The applied data is negatively skewed with an excess kurtosis of -0. 54564. The residual graph and model evaluation criteria indicate that the model is stable and suitable for forecasting TB incidence in Oman. Figure 2 implies that the applied model ANN (9,12,1) simulates the observed data very well. The model predicts that the incidence of TB will be low and will reach a plateau level of 5.5 cases per 100 000 population throughout the period 2019-2023.

V. CONCLUSION & RECOMMENDATIONS

Oman is one the countries in the world which has managed to control TB infection successfully. Over the period 2000-2018 the country recorded TB incidence values below 30 cases/100 000 population and the incidence gradually declined from around 16 cases per 100 000/year in 2000 to around 6 cases per 100 000 in 2018.The model predicts that the incidence will remain low around 5,5 cases per 100 000 over the period 2019-2023.The government is encouraged to continue on this commendable path to ensure effective control of the TB epidemic.

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