International Research Journal of Innovations in Engineering and Technology (IRJIET)

ISSN (online): 2581-3048

Volume 5, Issue 3, pp 166-171, March-2021

https://doi.org/10.47001/IRJIET/2021.503029

Forecasting Art Coverage in Zambia Using Artificial Neural Networks

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***Abstract* - In this research article, the ANN approach was applied to analyze ART coverage in Zambia. The employed 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 ART coverage in Zambia. The results of the study indicate that ART coverage will be high around 80% over the out of sample period. We encourage the government to intensify test and treat approach, strengthen TB/HIV collaboration and create more demand for ART services through mass media communication.**

Keywords: ANN, ART coverage, Forecasting.

I. INTRODUCTION

Developing countries need to scale up HIV testing and antiretroviral therapy coverage to ensure that they reach their set targets by the end of 2030.These governments should design local plans which are practical and less costly in order to achieve their goals. Public health authorities should ensure that there is enough health personnel to implement ART program activities such as demand creation and advocacy, HIV testing, prescribing and dispensing of antiretroviral therapy drugs, program monitoring and evaluation, and support supervision of clinical staff at all levels of the health delivery system. Increasing HIV testing capacity has been noted to be the key component in the scale up of antiretroviral coverage in low and middle income countries (Habiyambere et al, 2016; Roberts, 2016; WHO, 2018). Community and clinic based HIV testing and dispensing of antiretroviral therapy for people living with HIV(PLWHIV) should be considered so that 2030 targets are achieved. Engagement of political leaders in the communities is critical in order to optimize HIV testing. Several developing countries are suffering from poverty, natural disasters and civil conflict, therefore it is important to allocate resources equitably. Furthermore it is prudent for these nations to prioritize HIV prevention strategies seriously for them to win the fight against the dual epidemic of HIV and TB .The prevention strategies which were recommended by WHO include condom distribution and use, bahavioural intervention strategies, Pre –exposure prophylaxis, Post exposure prophylaxis, prevention of mother to child transmission of HIV (PMTCT) and voluntary medical male circumcision. These strategies will help save a lot of financial resources in the long run, however if these preventive measures are not taken seriously or prioritized developing nations are likely to witness increasing morbidity and mortality due to TB/HIV aggravated by poverty ,hunger, and political conflicts. At this point ,it is ideal to model and forecast ART coverage in developing countries in order to understand the possible future trends of ART coverage and assess the progress towards achieving the global targets by 2030.Several models have been applied in literature which include machine learning techniques ,exponential smoothing and Autoregressive integrated Moving Average (ARIMA) models (Nyoni et al, 2020). Machine learning techniques includes artificial neural networks (ANNs), support vector machine (SVM),ensembles and Bayesian Networks (Weng, 2017, Nyoni et al, 2020). ARIMA models were proposed by Box and Jenkins in 1970. The ARIMA model is specified in the form ARIMA(p,d,q) where p and q are non-seasonal autoregressive (AR) and moving average (MA) parts ,d representing the number of non-seasonal differences (Nyoni & Nyoni 2019a & b; Kaushiki and Sahi, 2018). The ARIMA(0,1,0) is popularly known as the Random Walk (RW) process, ARIMA (1,0,0) is the first order autoregressive process or AR (1) model ,ARIMA (0,0,1) is the first order moving average process also known as the MA(1) process and ARIMA (1,0,1) is the ARMA(1,1) process.

In this study we applied the artificial neural network, multilayer perceptron (MLP) to forecast the ART coverage in Zambia. The ANN (9, 12, 1) model was utilized to generate the forecasts, where 9,12,1 represent the number of input, hidden and output nodes respectively (Fojnica et al, 2016; Zhang, 2003; Yan et al, 2018).The hyperbolic tangent function was chosen as the ideal activation function. The results of the study are expected to act as a surveillance tool for the control of the HIV epidemic in Zambia as well as evaluation of the impact of HIV care and treatment programs in the country.

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II. LITERATURE REVIEW

Floyd et al (2019) assessed the feasibility of achieving the first two targets, and the corresponding 81% ART coverage target, as part of the HIV Prevention Trials Network (HPTN) 071 Population Effects of Antiretroviral Therapy to Reduce HIV Transmission (PopART) community-randomized trial. The study population was individuals aged >15 years living in 14 urban and peri-urban "PopART intervention" communities in Zambia and South Africa (SA), with a total population of approximately 600,000 and approximately 15% adult HIV prevalence. Community HIV care providers (CHiPs) delivered the PopART intervention during 2014–2017. This was a combination HIV prevention package including universal home-based HIV testing, referral of HIV-positive individuals to government HIV clinic services that offered universal ART (Arm A) or ART according to national guidelines (Arm B), and revisits to HIV-positive individuals to support linkage to HIV care and retention on ART. The intervention was delivered in 3 "rounds," each about 15 months long, during which CHiPs visited all households and aimed to contact all individuals aged >15 years at least once. The findings study showed that very high HIV testing and treatment coverage can be achieved through persistent delivery of universal testing, facilitated linkage to HIV care, and universal treatment services. The ART coverage target of 81% was achieved overall, after 4 years of delivery of the Pop ART intervention, though important gaps remained among men and young people. The findings were consistent with previously reported findings from southern and east Africa, extending their generaliz ability to urban settings with high rates of in-migration and mobility and to Zambia and SA. Kancheya et al (2010) conducted serial cross-sectional surveys on the University Teaching Hospital medical ward to assess HIV prevalence among inpatients of unknown status in 2003 and 2006. Willing participants received counseling and dual HIV rapid tests. The research compared the proportion of inpatients receiving their test results in 2003 (off the-ward testing) to 2006 (on-the-ward).The study showed that after ART program expansion, inpatients in 2006 were far more likely than their 2003 counterparts to know their HIV status and to be taking ART. In both years, 63-73% of medical inpatients were HIV-infected and 98.5% of inpatients agreed to test. On-the-ward testing in 2006 avoided the 2003 problem of patient discharge before learning of their test results. Hospital-based HIV testing is an essential clinical service in high prevalence settings and can serve further as a surveillance system to help track the community impact of outpatient AIDS services in Africa .Johnson et al (2017) assessed South Africa's progress towards the 2020 targets and variations in performance by province .A mathematical model was fitted to the HIV data for each of South Africa's provinces and for the country as a whole .The study results revealed that ART coverage varied between 43% in Gauteng and 63 % in Northern Cape and most provinces face challenges in reaching the remaining two 90% targets. A mathematical modelling approach was also applied by Hontelez et al (2013).In the study nine mathematical models were developed for South Africa's HIV epidemic elimination. All models confirmed previous predictions that the HIV epidemic in South Africa can be eliminated through universal testing and immediate treatment at 90 % coverage. Adam &Johnson (2009) estimated adult antiretroviral treatment coverage in South Africa using the Markov model .The findings of the study showed that ART coverage in 2008 varied between Provinces from 25.8% in the Free State to 71.7%.

III. METHOD

The Artificial Neural Network (ANN), which we shall employ in this study; 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 Zambia 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 annual ART coverages (referred to as Z series in this study) in all age groups Zambia. The 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 data base.

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IV. FINDINGS OF THE STUDY

DESCRIPTIVE STATISTICS

Table 1: Descriptive statistics

Mean	Median	Minimum	Maximum
31.632	29.000	0.00000	78.000
Std. Dev.	C.V.	Skewness	Ex. kurtosis
27.437	0.86740	0.25811	-1.3854
5% Perc.	95% Perc.	IQ range	Missing obs.
Undefined	78.000	55.000	0

ANN MODEL SUMMARY FOR ART COVERAGE IN ZAMBIA

Table 2: ANN model summary

Variable	Z
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	0.037228
MSE	2.602498
MAE	1.182433

Residual Analysis for the ANN model

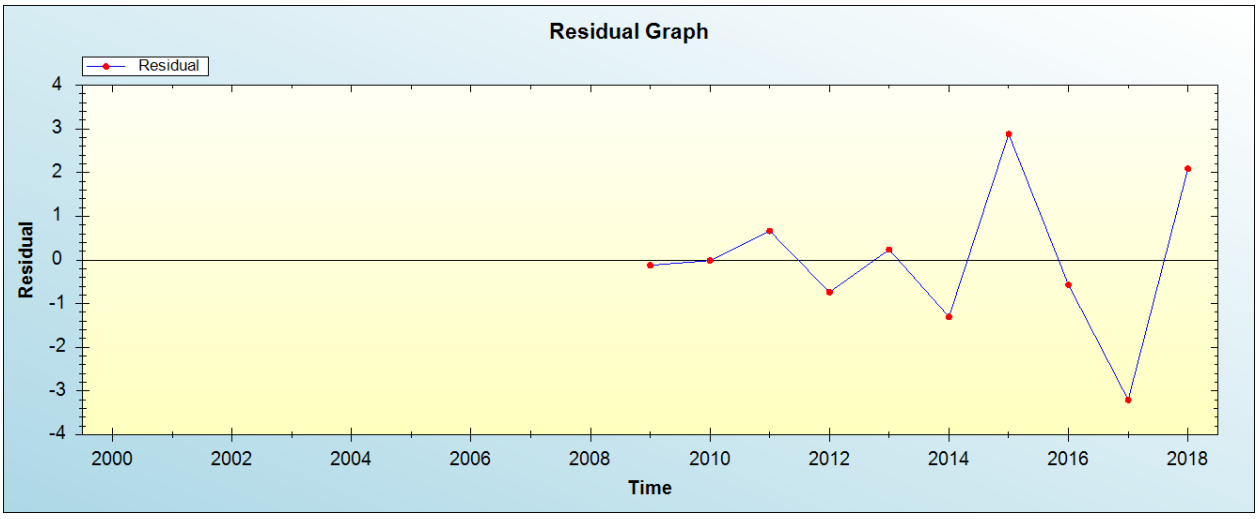

Figure 1: Residual analysis

In-sample Forecast for Z

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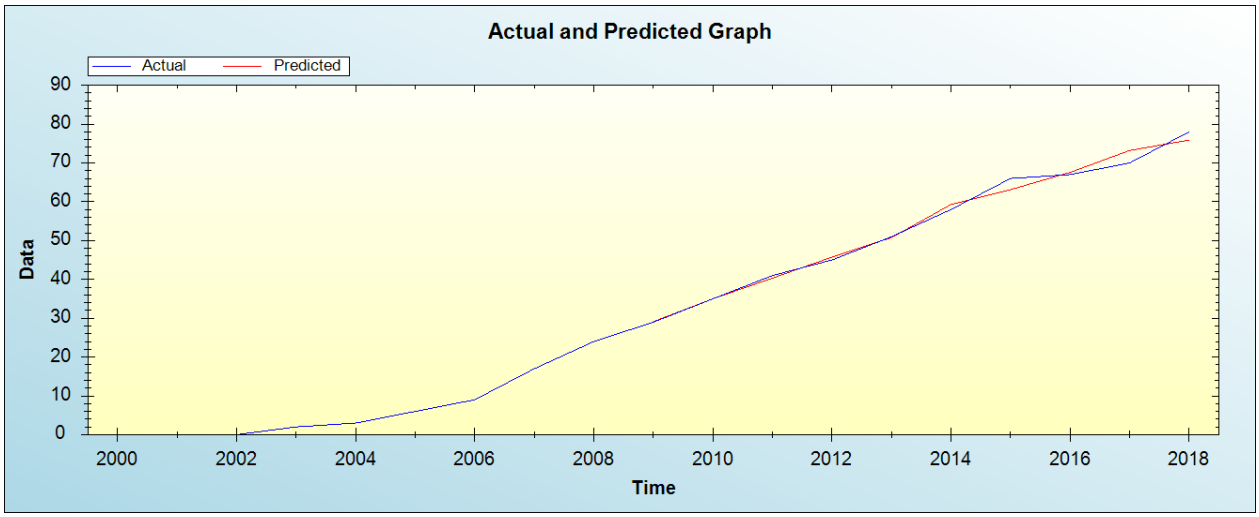

Figure 2: In-sample forecast for the Z series

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

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

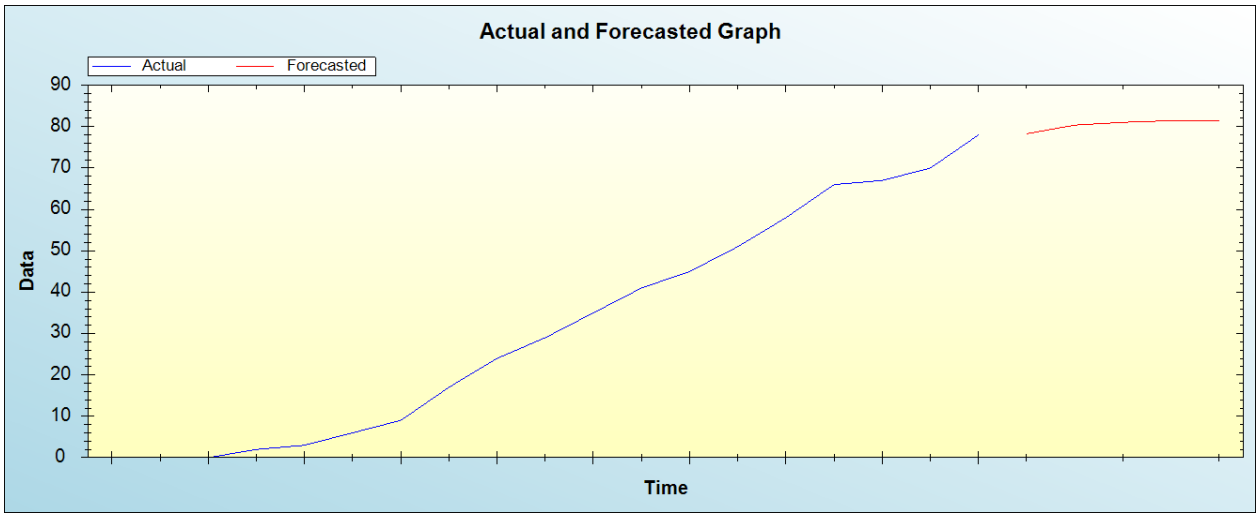

Figure 3: Out-of-sample forecast for Z: actual and forecasted graph

Out-of-Sample Forecast for Z: Forecasts only

Table 3: Tabulated out-of-sample forecasts

Year	Forecasted ART coverage
2019	78.2812
2020	80.3714
2021	81.0380
2022	81.4405
2023	81.4324

Over the study period, the minimum and maximum ART coverage was 0 and 78% respectively with an average of 31.6 %. The national ART program was rolled out in 2003 hence zero reporting of ART coverage was noted for the period 2000-2002. The data employed in this study is positively skewed with an excess kurtosis of -1.38 meaning that the data is not normally distributed. The residual graph and model evaluation criteria indicate that the model is stable and suitable for forecasting ART

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coverage in Zambia. In-sample forecasts revealed that the applied model simulate the observed data very well. The model predicted that ART coverage will be high around 80 % over the period 2019-2023.

V. CONCLUSION & RECOMMENDATIONS

Over the period 2019-2023, the country recorded an upward trajectory of ART coverage showing the government's interest in improving access to antiretroviral therapy. The model predicts ART coverage will be high around 80 % over the out of sample period. The authorities are encouraged to strengthen TB/HIV collaboration, intensify test and treat approach and create more demand for ART services through mass media communication.

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ISSN (online): 2581-3048
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Citation of this Article:

Dr. Smartson. P. NYONI, Thabani NYONI, "Forecasting Art Coverage in Zambia Using Artificial Neural Networks" Published in *International Research Journal of Innovations in Engineering and Technology - IRJIET*, Volume 5, Issue 3, pp 166-171, March 2021. Article DOI https://doi.org/10.47001/IRJIET/2021.503029

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