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# Botswana's Art Program Success Story: Evidence from the Artificial Neural Networks

**[1]Dr. Smartson. P. NYONI, [2]Thabani NYONI**

[1]ZICHIRe Project, University of Zimbabwe, Harare, Zimbabwe
[2]Department of Economics, University of Zimbabwe, Harare, Zimbabwe

***Abstract* - In this research article, the ANN approach was applied to analyze ART coverages in Botswana. 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 ART coverage in Botswana. The ANN (9, 12, 1) model predictions suggests that the country is likely to record an upward trend in the annual ART coverage over the period 2019-2023, from 84% in 2019 to 86% in 2023 .The government of Botswana is strongly encouraged to improve ART access to key populations such foreigners, commercial sex workers and MSMs .The health authorities are also encouraged to increase demand for ART services through mass media communication and should expand its HIV testing capacity.**

***Keywords:*** ANN, ART coverage, Forecasting.

## I. INTRODUCTION

Despite the scale up of antiretroviral treatment coverage at global level many countries are still suffering from the effects of the HIV pandemic (Moyo et al, 2018; Makhema et al, 2018). In 2017, 21.7 million people living with HIV were on antiretroviral therapy (ART) (HIV market report, 2018). Botswana is a high HIV prevalence country with 22.8% of its adult population living with HIV (UNAIDS, 2017). It is one of the African countries which was the first to offer HIV testing and to adopt the universal treatment policy regardless of CD4 count (MOH Botswana, 2016). The national ART was rolled out in Botswana in the year 2002 and provides free HIV care and treatment to citizens (Marukutira et al, 2019). However the country does not offer free ART services to non-citizens who usually end up having poor treatment outcomes because of lack of ART services (Tenser et al,2015; IOM, 2018). The national ART program continues to face challenges just like any other African countries and these include poor treatment adherence, loss to follow up, stigma and discrimination. Poor treatment adherence, treatment interruptions and loss to follow up of ART patients have been identified as one of the main factors which lead to drug resistance and treatment failure (Pallado et al, 2013; Anude et al, 2013; Bayu et al, 2017; Enderis et al, 2019; Ahmed et al, 2020 ). Botswana has made significant steps in the ART program .Over the period 2000-2018 the country reported an upward trend in ART coverage reflecting that more PLHIV are accessing ART.In this paper we aim to forecast ART coverage in Botswana using the artificial neural network (ANN) model. The ANNs together with Autoregressive Integrated Moving Average (ARIMA) models have been widely applied in predictive modeling across the globe. The ARIMA model is specified as ARIMA (p, d, q) where p and q are the non-seasonal autoregressive (AR) and moving average (MA) components represents the non-seasonal differencing order (Nyoni &Nyoni 2019 a &b). ARIMA model building is based on the three step iterative procedure as proposed by Box and Jenkins in 1970. The methodology is characterized by model identification, parameter estimation and diagnostic checking. The ANN, multilayer perceptron is the commonest neural network model for time series forecasting. The model is made up of three layers which are the input, hidden and output layers. The layers are connected by acyclic links called connection weights. The nodes in each layer are processing elements. The model is able to handle complex and large data sets (Fojnica et al, 2016; Zhang, 2003; Yan et al, 2018). The findings of this piece of work are expected to enlighten the government of Botswana on the future trends of ART coverage and progress towards achieving the 2030 global targets. This will stimulate an early response to the HIV epidemic.

## II. LITERATURE REVIEW

Alwano et al (2019) implemented a multi-modality HIV testing approach to identify 90% or greater of HIV-positive persons in the Botswana Combination Prevention Project (BCPP) intervention communities. BCPP was a cluster-randomized trial designed to evaluate the impact of combination prevention interventions on HIV incidence in 30 communities in Botswana. Community case finding and HIV testing that included home and targeted mobile testing were implemented in the 15 intervention communities. The study described processes for identifying HIV-positive persons, uptake of HIV testing by age, gender and

 

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venue, characteristics of persons newly diagnosed through BCPP, and coverage of knowledge of status reached at the end of study. The findings of the study revealed that even when HIV testing coverage is high, additional gains can be made using a multi-modality HIV testing strategy to reach different sub-populations who are being missed by non-targeted program activities. Men and youth can be reached and will engage in community testing when services are brought to places they access routinely. In another research paper, Marukutira et al (2019) conducted community case finding and HIV testing were in home and mobile venues in 15 intervention communities from October 2013-September 2017. In this secondary analysis, the study compared HIV positivity, knowledge of positive HIV-status, and ART status among all citizens and non-citizens assessed at intake in the intervention communities. The study concluded that although non-citizens were less likely to know their HIV-positive status compared to citizens, there were no differences in treatment uptake among non-citizens and citizens who knew their status. Designing interventions for non-citizens that provide HIV testing and treatment services commensurate to that of citizens as well as targeting communities with the largest number of non-citizens may help close a meaningful gap in the HIV care cascade and ensure ethical treatment for all HIV-positive persons. In another study, 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 intend to employ; 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 Botswana 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 annual ART coverages (referred to as G series in this study) in all age groups in Botswana. 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 the World Bank online database.

## IV. FINDINGS OF THE STUDY

### DESCRIPTIVE STATISTICS

**Table 1: Descriptive statistics**

| Mean | Median | Minimum | Maximum |
|---|---|---|---|
| 40.053 | 42.000 | 0.00000 | 83.000 |
| Std. Dev. | C.V. | Skewness | Ex. kurtosis |
| 28.485 | 0.71119 | -0.035995 | -1.3979 |
| 5% Perc. | 95% Perc. | IQ range | Missing obs. |
| Undefined | 83.000 | 53.000 | 0 |

### ANN MODEL SUMMARY FOR ART COVERAGE IN BOTSWANA

**Table 2: ANN model summary**

| Variable | G |
|---|---|

 

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| | |
|---|---|
| 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 | 0.010137 |
| MSE | 0.218503 |
| MAE | 0.364301 |

*Residual Analysis for the ANN model*

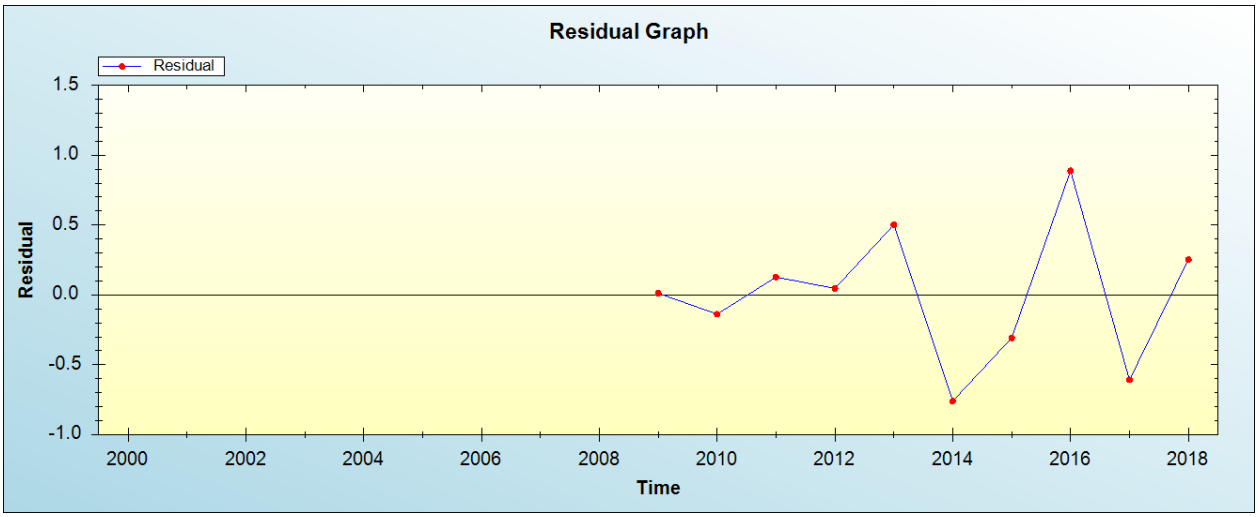


**Figure 1: Residual analysis**

*In-sample Forecast for G*

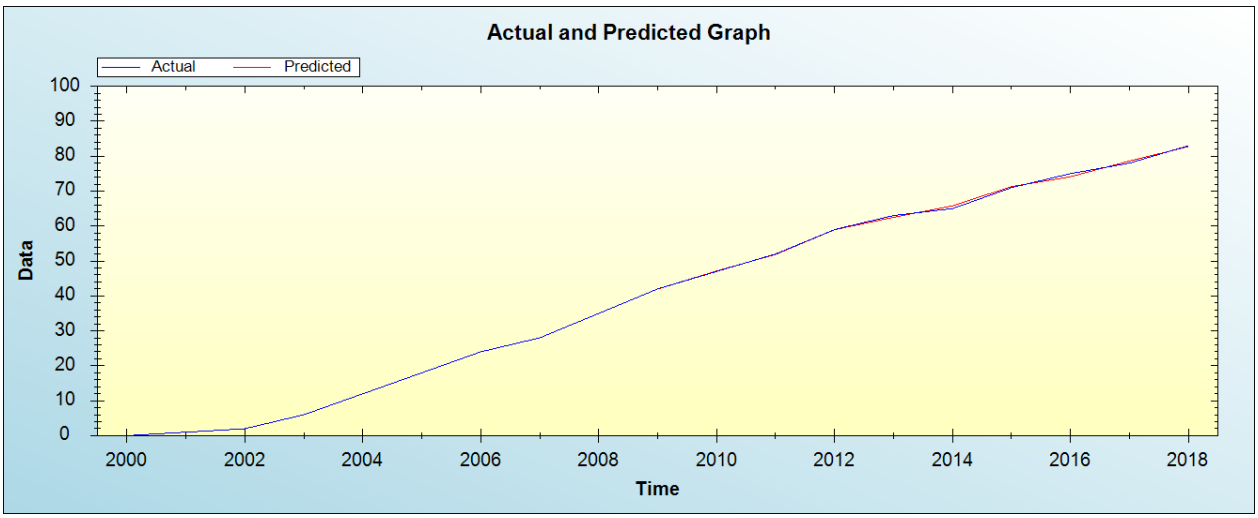


**Figure 2: In-sample forecast for the G series**

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

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

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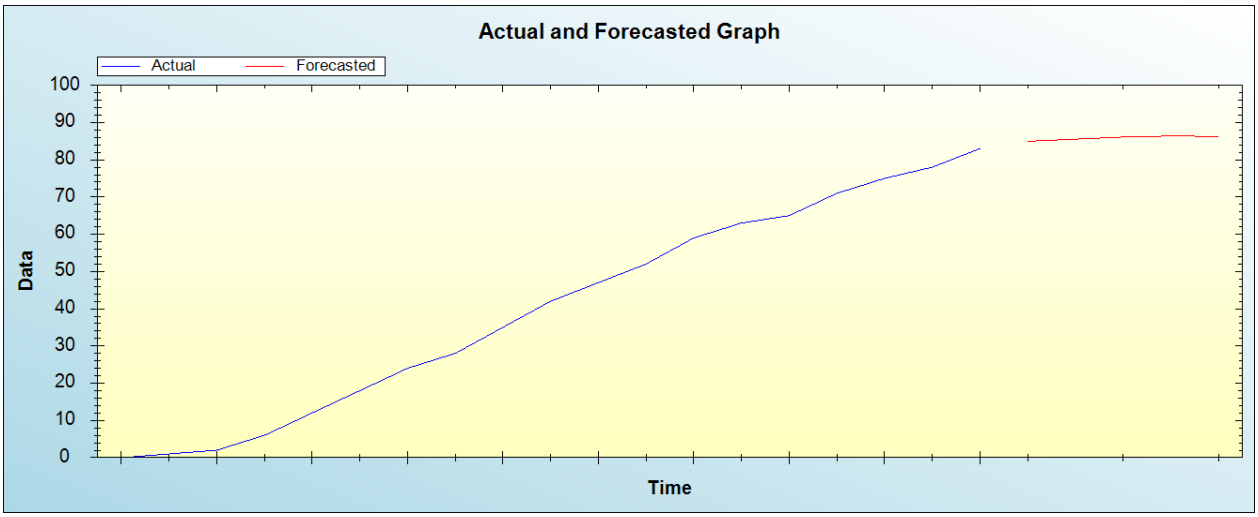


**Figure 3: Out-of-sample forecast for G: actual and forecasted graph**

*Out-of-Sample Forecast for G: Forecasts only*

**Table 1: Tabulated out-of-sample forecasts**

| Year | Forecasted ART coverage |
|---|---|
| 2019 | 84.9561 |
| 2020 | 85.5309 |
| 2021 | 86.0922 |
| 2022 | 86.3749 |
| 2023 | 86.2854 |

Over the study period 2000-2018, the minimum and maximum ART coverage was 0 and 83% respectively. The country recorded zero ART coverage in 2000 because ART service the country started offering ART services in 2001. The average ART coverage was 40% over the study period. The data is negatively skewed with an excess kurtosis of -1.3979 meaning that the ART coverage data over the period 2000-2018 is not normally distributed. The model evaluation criteria (Error, MSE, MAE) and the residual graph indicate that the applied ANN (9, 12, 1) model is stable and suitable for forecasting ART coverage in Botswana. The In-sample forecasts reveal that the applied neural network model fits the observed ART coverage data very well. Predictions from the model suggest that ART coverage will increase from around 84 % in 2019 to approximately 86 % in 2023. This means Botswana is likely to improve in terms of increasing access to antiretroviral therapy to people living with HIV (PLHIV).

## V. CONCLUSION & RECOMMENDATIONS

Botswana has made significant milestones in the provision of antiretroviral therapy to people living with HIV and this is demonstrated by an observed upward trend in the ART coverage over the period 2000-2018. New HIV infections have dropped significantly from 18000 in 2005 to 10 000 in 2010 and a further decline to 8500 in 2018(UNAIDS,2018).The ANN (9,12,1) model predictions suggests that the country will improve in the provision of ART services to people living with HIV. The model projects an upward trend of ART coverage from around 84 % in 2019 to about 86% in 2023. However the government is strongly encouraged to provide free ART services to foreign nationals and key populations in the country as well as increasing demand for ART services in the community and scaling up HIV testing services through TB/HIV program collaboration.

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