

# Forecasting Art Coverage in the Kingdom of Eswatini Using Artificial Neural Networks

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**Abstract** - In this research article, the ANN approach was applied to analyze ART coverage in the Kingdom of Eswatini. 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 Eswatini Kingdom. The ANN (9, 12, 1) model predictions suggest that the Kingdom is likely to record a high ART coverage which will be around 88% over the period 2019-2023. The authorities should therefore strengthen TB/HIV collaboration, create more demand for ART services and strengthen tracking of loss to follow up ART clients to improve adherence and clinical outcomes of HIV/TB treatment.

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

## I. INTRODUCTION

Eswatini is struggling to control the HIV epidemic. The country has the highest HIV prevalence in the World (UNAIDS, 2019; World Bank, 2019). According to UNAIDS, 2020 reports, in 2019 the estimated number of people living with HIV (PLHIV) was 200 000 with adult (15-49 years) HIV prevalence of 27% and 2300 cumulative deaths related to AIDS. The country reported 4800 new HIV infections and more than 95% adults were on antiretroviral treatment (ART). The nation has the highest HIV prevalence among sexworkers in the world (UNAIDS, 2020). The Kingdom of Eswatini has a generalized HIV epidemic, however sexworkers, adolescent girls, young women and men who have sex with men are more affected than others (UNAIDS, 2019). In 2018, 23 000 young people aged 15-24 were living with HIV in Eswatini (UNAIDS, 2019). Young women are at a higher risk of acquiring HIV infection, 15.9% young women were living with HIV in 2018 compared to 3.1% of their male counterparts. The National ART program is not only concerned with detection and treatment of HIV cases but also values HIV prevention. The HIV prevention in the country is outlined in the National Multisectoral HIV and AIDS strategic Framework (NSF) 2018-2023. The Combined HIV prevention strategy encompasses condom distribution and use, behavioral change interventions, Prevention of Mother to Child transmission of HIV (PMTCT), voluntary medical male circumcision (VMMC), pre exposure prophylaxis and post exposure prophylaxis (Eswatini, 2018; UNAIDS, 2016; PEPFAR 2017; PEPFAR, 2019; Swaziland Ministry of Health, 2014; Eswatini Ministry of Health, 2018). ART services are offered for free in public health facilities and the country adopted the WHO test and treat approach. The program is funded by PEPFAR and the Global fund for AIDS, Malaria and TB. In 2018, 86 % of PLHIV in Eswatini were on ART and 81% of PLHIV had viral load suppression (PEPFAR, 2019; UNAIDS, 2019). Eswatini has a dual epidemic of HIV and TB 65% of TB patients also infected with the HIV virus. There is evident TB/HIV collaboration. All TB patients who visit medical facilities are offered HIV testing services and HIV positive patients are screened for TB. Patients taking ART are offered TB preventive therapy (PEPFAR, 2019; Eswatini, 2018). The purpose of this study is to predict ART coverage in the Kingdom of Eswatini using the artificial neural network (ANN) model. The results of the study are expected to provide an insight of the future progress towards achieving the global goal of ending the HIV epidemic as a public health threat by 2030. Furthermore, the findings will act as a surveillance tool and stimulate an appropriate response to the HIV epidemic in the country.

## II. LITERATURE REVIEW

Minnery et al (2019) applied an Optima HIV model to estimate the impact of efficiency strategies to accelerate prevention of HIV infections and HIV-related deaths. The study estimated the number of infections and deaths that could be prevented by optimizing HIV investments. Optimization was done across HIV programs, then across service delivery modalities for voluntary medical male circumcision (VMMC), HIV testing, and antiretroviral refill, as well as switching to a lower cost antiretroviral regimen. The Study found out that under an optimized budget, prioritizing HIV testing for the general population followed by key preventative interventions may result in approximately 1,000 more new infections (2% more) being averted by 2023. More

infections could be averted with further optimization between service delivery modalities across the HIV cascade. Scaling-up index and self-testing could lead to 100,000 more people getting tested for HIV (25% more tests) with the same budget. By prioritizing Fast-Track, community-based, and facility-based antiretroviral refill options, an estimated 30,000 more people could receive treatment. Moyo et al (2017) examined changes and equity in ART use in Kenya and South Africa. The study analyzed national population based household surveys conducted in Kenya and South Africa between 2007 and 2012 for factors associated with lack of ART use among people living with HIV aged 15-64 years. The findings from the study revealed that ART use among PLHIV increased from 29.3% to 42.5% from 2007 to 2012 in Kenya and 17.4% to 30.3% from 2008 to 2012 in South Africa. Areas needing improvement include rural Kenyans, students in South Africa and among young people and drug users in both countries. Levira et al (2015) evaluated adult ART and pre ART care coverage by age and sex at CD4 <200, <350 and all people living with HIV in the Rufiji district of Tanzania from 2006 to 2010. The ALPHA model was used to predict the number in need of pre ART and ART by age and sex at CD4 <200 and CD4 <350. The study concluded that ART coverage in the Rufiji District was unevenly distributed and far from universal coverage target of 80% in particular among young men.

### III. METHOD

The Artificial Neural Network (ANN) is just 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 Swaziland (now eSwatini) 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 coverage (referred to as P series in this study) in all age groups in the Kingdom of Eswatini. 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 database.

### IV. FINDINGS OF THE STUDY

#### DESCRIPTIVE STATISTICS

Table 1: Descriptive statistics

Mean	Median	Minimum	Maximum
34.526	28.000	0.00000	86.000
Std. Dev.	C.V.	Skewness	Ex. kurtosis
30.266	0.87661	0.43739	-1.1774
5% Perc.	95% Perc.	IQ range	Missing obs.
undefined	86.000	57.000	0

#### ANN MODEL SUMMARY FOR ART COVERAGE IN THE KINGDOM OF ESWATINI

Table 2: ANN model summary

Variable	P
Observations	P (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	0.028053
MSE	1.796416
MAE	1.097729

*Residual Analysis for the ANN model*

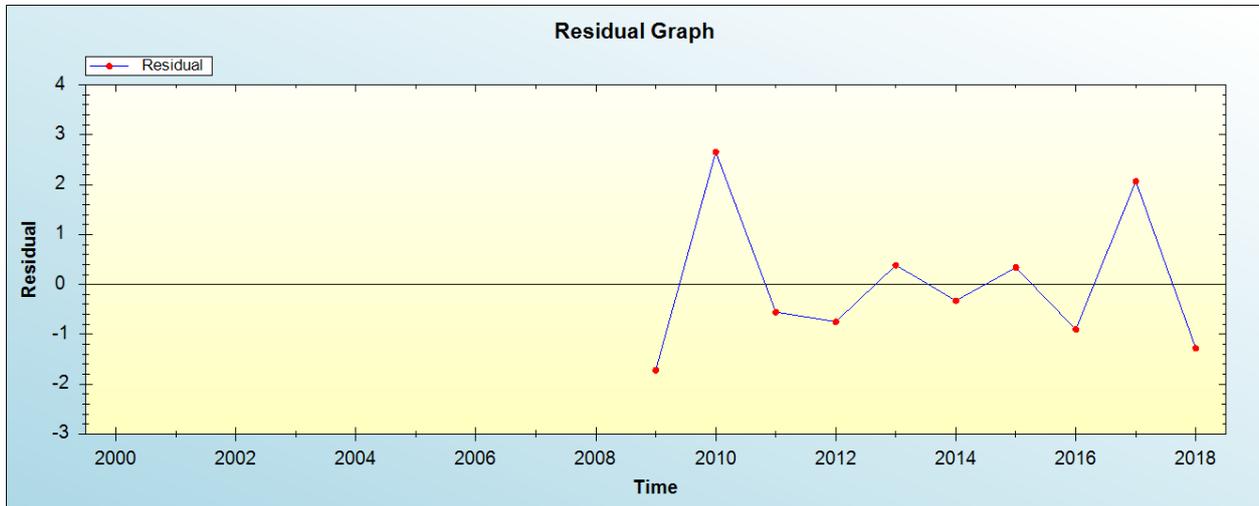


Figure 1: Residual analysis

*In-sample Forecast for P*

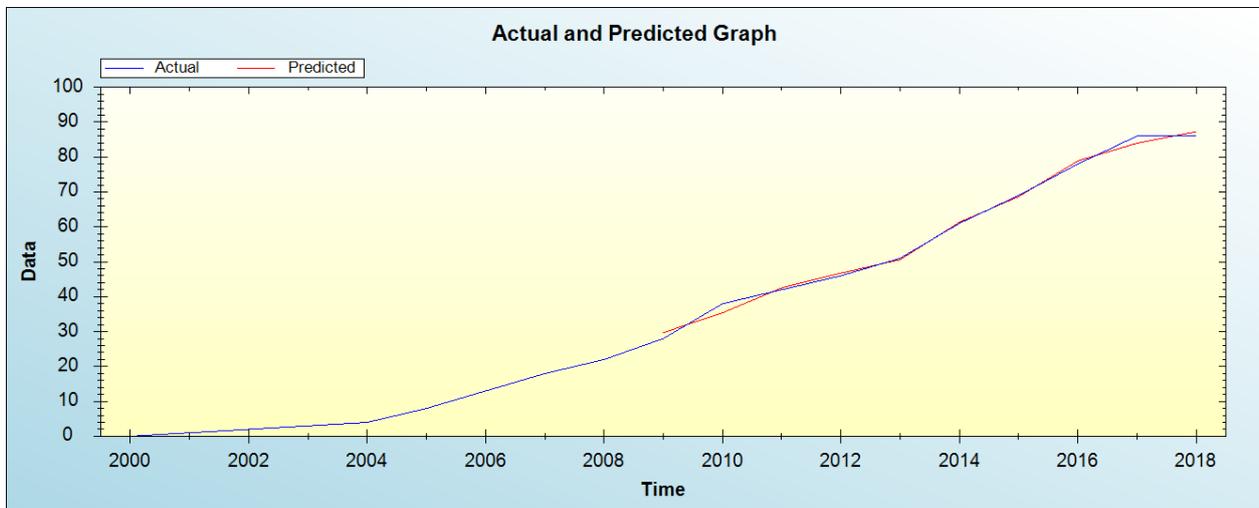


Figure 2: In-sample forecast for the P series

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

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

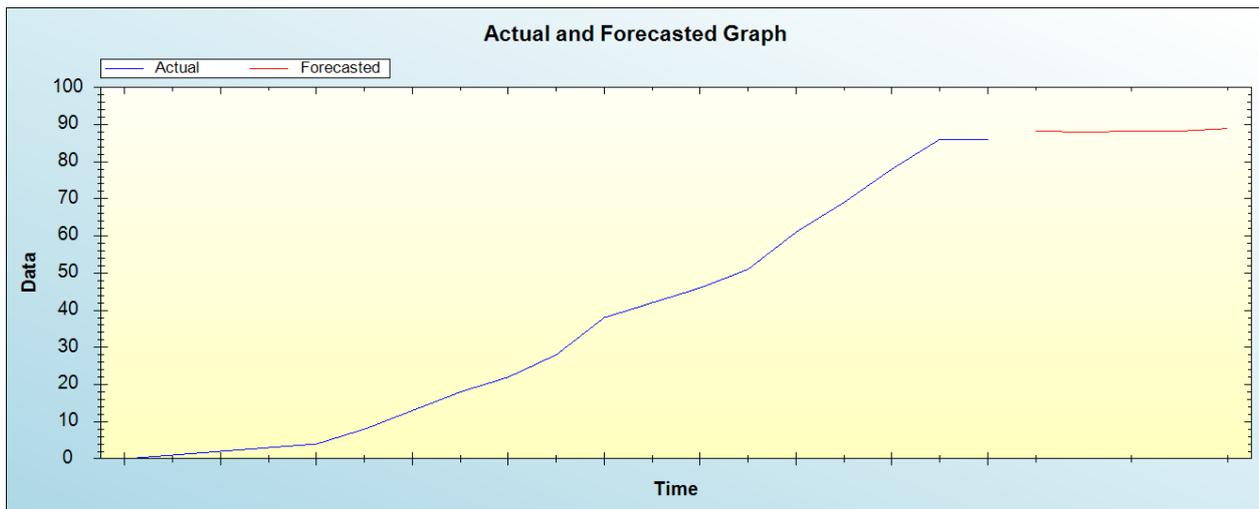


Figure 3: Out-of-sample forecast for P: actual and forecasted graph

Out-of-Sample Forecast for P: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted ART coverage
2019	88.2068
2020	87.9999
2021	88.1708
2022	88.2053
2023	88.9325

Over the study period the minimum and maximum ART coverage was 0 and 86 % respectively with an average of 34 %. The data used in this study is positively skewed with excess kurtosis of -1.1774 meaning the data is not normally distributed. The residual graph and model evaluation criteria (Error, MSE, MAE) indicate that the applied model is stable and suitable for forecasting ART coverage in the Kingdom of Eswatini. The in-sample forecasts showed that the neural network model simulates the observed data very well. The model projections suggest that ART coverage is likely to remain high around 88 % throughout the period 2019-2023.

## V. CONCLUSION & RECOMMENDATIONS

The Kingdom of Eswatini has made significant strides in improving access to ART for people living with HIV in the country. Over the period 2000-2018, the nation has recorded an upward trend in ART coverage. The model predictions suggested that ART coverage will be high around 88 % in the forecast period. This clearly shows that the country is on track in ensuring access to antiretroviral therapy for people living with HIV. However the government must continue strengthening TB/HIV collaboration, create more demand for HIV testing services and strengthen tracing of loss to follow up ART clients to improve adherence and clinical outcomes of HIV treatment.

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