Prediction of Art Coverage in Lesotho Using Artificial Neural Networks

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Abstract - **In this research paper, the ANN approach was applied to analyze ART coverage in Lesotho. 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 Lesotho. The ANN (9,12,1) model predicted that the ART coverage will likely be around 63 % throughout the period 2019-2023.Therefore the government is encouraged to strengthen the system of tracking loss to follow up ART patients ,create more demand for ART services and increase HIV testing capacity at all levels of the health delivery system.**

Keywords: ANN, ART coverage, Forecasting.

I. INTRODUCTION

Lesotho is a small SADC country with a population close to 2million people and an annual income of $ 1.210 per capita with 70% of the population residing in the rural areas (World Bank, 2017). Over the period 2016-2017 the prevalence of HIV among the 15-19 age group of 25.6% with an incidence of 1.5 new infections per 100 person years of exposure (PBHAP, 2018). Antiretroviral therapy coverage among people living with HIV is around 69.6% (PBHAP, 2018). The number of AIDS related deaths in 2016 was 9.900 (PEPFAR, 2018). HIV/AIDS has negative effects on the country's health, education, agriculture and economic development.

It is the leading cause of mortality and contributed about 56 % of deaths among children below 5 years of age (WHO, 2008; UNAIDS, 2014; Wang et al, 2016). The national ART program in Lesotho is mainly funded by PEPFAR and Global Fund and HIV care and treatment is offered for free at all levels of the health delivery system. The objective of the program is to achieve the UNAIDS set targets of ending the HIV epidemic as a public health problem by 2030. Antiretroviral drugs suppress the replication of the HIV virus, improve the quality of life, prolong life and subsequently reduce the transmission of HIV .Effective HIV care and treatment programs significantly help in the reduction of morbidity and mortality due to HIV. Lesotho has nearly achieved 100 % HIV testing coverage among patients in PEPFAR supported Health care facilities. The country has managed to implement both health care facility and community based HIV testing and treatment (PEPFAR, 2017). There are many ART program challenges in Lesotho which include poor adherence, treatment interruption, stigma and discrimination and emergence of drug resistant HIV strains which have led to poor treatment outcomes and very costly second and third line antiretroviral therapy (Urassa et al, 2018). The country adopted the treat and test approach as well as the WHO recommendation to commence ART on all HIV positive patients regardless of CD4 T cell count and clinical staging (PEPFAR, 2017). The nation has also adopted the WHO combined HIV prevention strategy in order to prevent and control the HIV epidemic. The strategy is constituted by condom distribution and use, voluntary medical male circumcision, Prevention of Mother to Child Transmission of HIV, Pre and Post exposure prophylaxis (PEPFAR, 2019; UNAIDS, 2019; PEPFAR, 2020, UNAIDS, 2020).In this study we applied the artificial neural network model, ANN(9,12,1) to predict annual coverage in Lesotho. The findings of this piece of work are envisioned to provide an insight of the future trends of ART coverage and progress towards achieving the 2030 global targets of ending the HIV epidemic as a public threat. The neural network technique will be used as a tool to evaluate the impact of HIV care and treatment programs in Lesotho.

II. LITERATURE REVIEW

Cerutti et al (2016) reported prevalence of depressive symptoms and alcohol use disorder, and their potential association with adherence and viral suppression in adult patients on ART in ten clinics in rural Lesotho, Southern Africa. The results confirmed previously reported association of alcohol use disorder with adherence to ART, there was no association with viral suppression.

Vandendyck et al (2015) conducted a mixed method study to evaluate the pilot of community ART groups (CAG's) in Lesotho. At the end of 2012 CAGs were piloted in Nazareth clinic, a facility in rural Lesotho. In CAG's stable patients take turns to collect antiretroviral therapy (ART) for fellow group members. Kaplan-Meier techniques were used to estimate retention among stable patients in CAG and not in CAG. Eight focus group discussions with 40 purposively selected CAG members, nine village health workers, six community leaders and nine clinicians provided insights in how CAGs are perceived by different stakeholders. The thematic analysis approach was employed for data analysis. The findings of the research indicated that participation in CAG impacted positively on the lives of members, not only on their access to ART, but also on their life within the community. Axelsson et al (2015) explores the role of timing of ART intake, the information patients received from health workers, local adherence patterns, barriers to and facilitators of ART among 28 HIV-positive adults at the Senkatana HIV Clinic in Maseru, Lesotho. This qualitative, semi-structured interview study was carried out during February and March of 2011 and responses were analyzed inspired by the Grounded Theory method. Results were then compared and discussed between the authors and the main themes that emerged were categorized. The majority of the respondents reported having missed one or more doses of medicine in the past and it was a widespread belief among patients that they were required to skip the dose of ART if they were late. The study findings revealed that the main barriers to adherence were interruptions of daily routines or leaving the house without sufficient medicine. The use of mobile phone alarms, phone clocks and support from family and friends were major facilitators of adherence. . In another study, Johnson et al (2017) reported 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 indicated 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 huge number of simple and highly interconnected processing elements resembling a biological neural system. It has the capability of learning from an experimental data set to describe the nonlinear and interaction effects with astonishing 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 Lesotho 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 L series in this study) in Lesotho. 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
24.632	26.000	0.00000	61.000
Std. Dev.	C.V.	Skewness	Ex. kurtosis
21.734	0.88235	0.25120	-1.2850
5% Perc.	95% Perc.	IQ range	Missing obs.
undefined	61.000	40.000	0

ANN MODEL SUMMARY FOR ART COVERAGE IN LESOTHO

Table 2: ANN model summary

Variable	L
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	0.013920
MSE	0.222523
MAE	0.396512

Residual Analysis for the ANN model
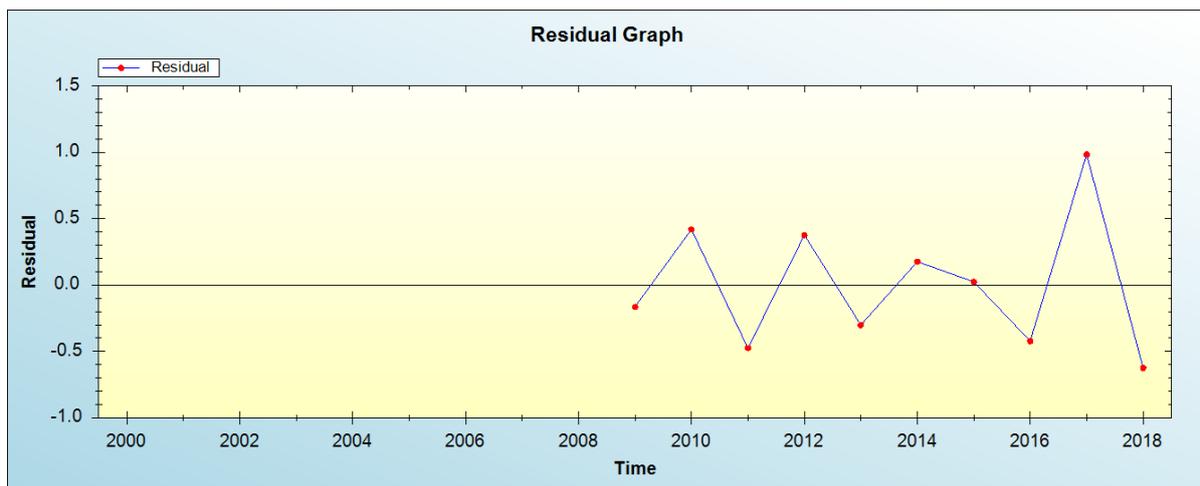
Figure 1: Residual analysis
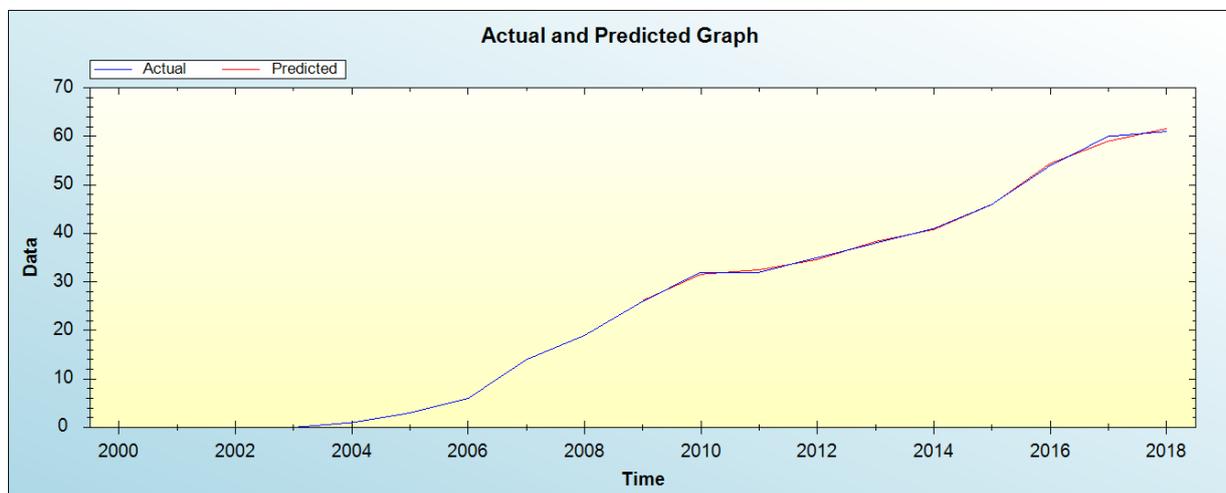
In-sample Forecast for L

Figure 2: In-sample forecast for the L series

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

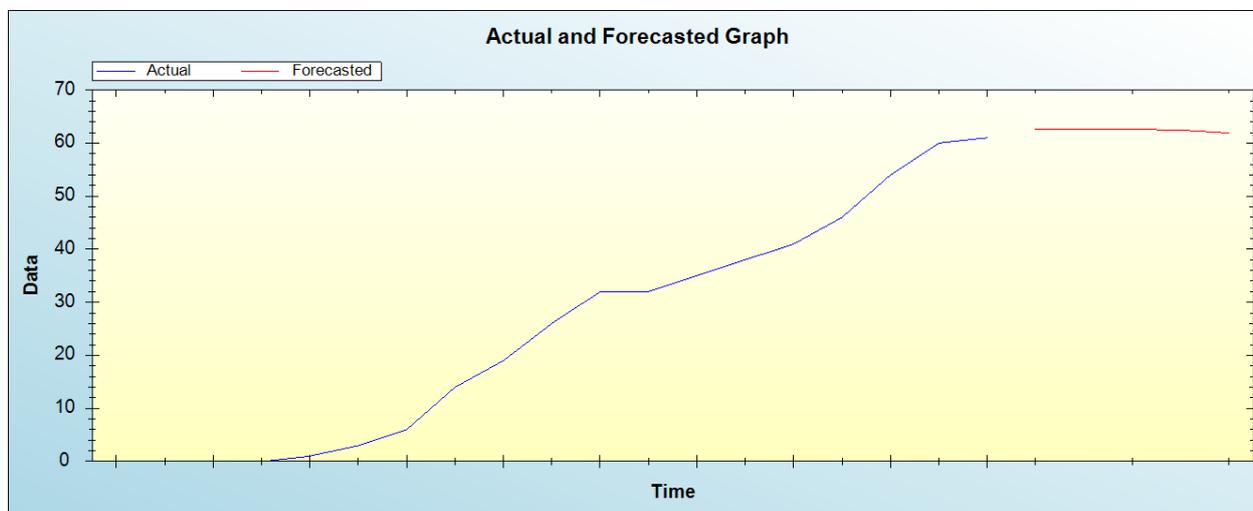*Out-of-Sample Forecast for L: Actual and Forecasted Graph*

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

Out-of-Sample Forecast for L: Forecasts only

Table 3: Tabulated out-of-sample forecasts

Year	Forecasted ART coverage
2019	62.6375
2020	62.6729
2021	62.6371
2022	62.4625
2023	61.9152

Over the study period, the minimum and maximum ART coverage was 0 and 61% respectively. The average ART coverage over the study period was 24.6%. The utilized data is not normally distributed. The residual graph and model evaluation criteria indicate that the applied ANN (9, 12, 1) model is stable and suitable for forecasting ART coverage in Lesotho. Figure 2 shows that the neural network model simulates the observed data very well. The model predicted that ART coverage is likely to be around 63 % over the period 2019-2023.

V. CONCLUSION & RECOMMENDATIONS

Lesotho recorded an improvement in the ART coverage over the period 2000-2018 characterized by an upward trend in ART coverage. However the country is still far away from achieving the 90-90-90 global goal in the fight against the HIV epidemic. The model predicted that over the period 2019-2023, the country is likely to record ART coverage of approximately 63 %. The government is therefore encouraged to address aggressively the issue of antiretroviral therapy access in the country by paying particular attention to strengthening the system of tracking loss to follow up ART patients, increasing HIV testing capacity and creating demand for ART services through mass-media sensitization.

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