Forecasting Art Coverage in Malawi Using the Multilayer Perceptron Neural Network

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Abstract - **In this study, the ANN approach was applied to analyze ART coverage in Malawi. 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 ANN (9, 12, 1) indicate that the model is stable in forecasting ART coverage in Malawi. The results of the study indicate that ART coverage is likely increase slightly over the period 2019-2023. The government is encouraged to create more demand for ART and HIV testing services, increase HIV testing capacity and strengthen tracking of loss to follow up ART patients amongst other measures**

Keywords: ANN, ART coverage, Forecasting.

I. INTRODUCTION

The World Health Organization recommended the test and treat approach as well as the initiation of antiretroviral treatment (ART) in all people living with HIV (PLHIV) irrespective of the CD4 T cell lymphocyte count and WHO clinical staging. These recommendations have triggered an increase in antiretroviral coverage in low and middle income countries. Several African countries including Malawi have been tasked to ensure free access of antiretroviral therapy to all people living with HIV. Access to ART has been noted by many researchers as an issue of concern in developing nations since some PLHIV ends up failing to get their ART services in time (IOM, 2018; Tanser, 2015). Barriers of accessing ART can be categorized into patient, healthcare worker, health facility and societal factors. Stigma and discrimination, incorrect information and poor services at public health institutions have been noted as common barriers for getting quality ART services. Many children in developing countries face transportation challenges and some of the residential areas are inaccessible by motor vehicles. Therefore it is necessary to engage community based or village health care workers to follow up such patients (Urassa et al, 2018).

The scale up of HIV care and treatment services requires political or leadership commitment and engagement of all stakeholders in the country. Increasing HIV testing in the community and health facilities is envisioned to increase ART coverage since more people living with HIV will be identified and enrolled on ART (WHO, 2018; Drain & Rousseau, 2017; WHO, 2016; Habiyambere et al, 2016; Roberts et al, 2016; UNITAID, 2015; WHO, 2015; WHO, 2008). Demand creation for HIV testing ought to be prioritized so as to maximize the number of people enrolled in ART. Outreach programs should incorporate demand creation officers who will have a specific task of reaching out to key populations in the community as well as adolescents and children. Proper management of patients on ART at health facility level is vital. Clinicians should prescribed medications properly order important investigations in time and follow up patients to monitor emergence of adverse events or complications of treatment, adherence and development of drug resistant HIV strains. There should be TB and HIV collaboration.

All patients on ART should have TB screening and should be offered TB preventive therapy if they do not have TB. In the same vein all TB patients must have HIV testing. The integration of TB and HIV programs will help control the dual epidemic of TB and HIV (PEPFAR, 2020; PEPFAR, 2019; WHO, 2018).

In this paper it is therefore critical to forecast ART coverage in Malawi in order to get an insight of the future trends of ART coverage in the country and to assess progress towards achieving the global UNAIDS targets by 2030.

II. LITERATURE REVIEW

Stelzle et al (2020) estimated the proportion of men and women who would be eligible for PrEP and the number of HIV infections that could be averted in Malawi, Mozambique, and Zambia using prioritization based on age, sex, geography, and markers of risk. They analyzed the latest nationally representative Demographic and Health Surveys (DHS) of Malawi, Mozambique, and Zambia to determine the proportion of adults who report behavioral markers of risk for HIV infection. The

study used prevalence ratios (PRs) to quantify the association of these factors with HIV status. Using a multiplier method, they combined these proportions with the number of new HIV infections by district, derived from district-level modelled HIV estimates. Based on these numbers, different scenarios were analyzed for the minimum number of person-years on PrEP needed to prevent 1 HIV infection (NNP). The study results revealed that a large proportion of new HIV infections in these 3 African countries were estimated to occur among people who had either an STI or an NP in the past year, providing a straightforward means to set PrEP targets. Greater prioritization of PrEP by district, sex, age, and behavioral risk factors resulted in lower NNPs thereby increasing PrEP cost-effectiveness, but also diminished the overall impact on reducing new infections. Thiabaud et al (2020) did a systematic review to obtain a comprehensive overview of the socio-behavioral factors influencing HIV prevalence and incidence in Malawi. Development of a Python tool to automatically extract, process, and categorise open-access articles published from January 1st, 1987 until October 1st, 2019 in PubMed, PubMed Central, JSTOR, Paperity, and arXiV databases was done and then used a topic modelling algorithm to classify and identify publications of interest. The results showed that their software does not replace traditional systematic reviews, but it returns useful results to broad queries of open-access literature in under a week, without a priori knowledge. This produces a "seed data-set" of relevance which could be further developed. It identified known   factors and rare factors that may be specific to Malawi. Gupta-Wrighti (2020) investigated ART failure, drug resistance, and early mortality among patients with HIV admitted to hospital in Malawi. This observational cohort study was nested within the rapid urine-based screening for tuberculosis to reduce AIDS-related mortality in hospitalized patients in Africa (STAMP) trial, which recruited unselected (ie, irrespective of clinical presentation) adult (aged ≥18 years) patients with HIV-1 at admission to medical wards. Patients were included in our observational cohort study if they were enrolled at the Malawi site (Zomba Central Hospital) and were taking ART for at least 6 months at admission. Patients who met inclusion criteria had frozen plasma samples tested for HIV-1 viral load. Those with HIV-1 RNA of at least 1000 copies per mL had drug resistance testing by ultra-deep sequencing, with drug resistance defined as intermediate or high-level resistance using the Stanford HIVDR program. Mortality risk was calculated 56 days from enrolment. Patients were censored at death, at 56 days, or at last contact if lost to follow-up. The modelling strategy addressed the causal association between HIV multidrug resistance and mortality, excluding factors on the causal pathway (most notably, CD4 cell count, clinical signs of advanced HIV, and poor functional and nutritional status).The study concluded that Interventions are urgently needed and should target ART clinic, hospital, and post-hospital care, including differentiated care focusing on patients with advanced HIV, rapid viral load testing, and routine access to drug resistance testing. Prompt diagnosis and switching to alternative ART could reduce early mortality among inpatients with HIV. 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), which we intend to rely upon; is a data processing system consisting of a large number of simple and highly interconnected processing elements resembling a biological neural system. It has a reliable 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 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 ART coverage in Malawi 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 (reffered to as M series in this study) in all age groups in Malaysia. 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
29.316	23.000	0.00000	78.000
Std. Dev.	C.V.	Skewness	Ex. kurtosis
27.827	0.94921	0.40465	-1.3047
5% Perc.	95% Perc.	IQ range	Missing obs.
Undefined	78.000	55.000	0

ANN MODEL SUMMARY FOR ART COVERAGE IN MALAWI

Table 2: ANN model summary

Variable	M
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	0.020614
MSE	0.797927
MAE	0.854671

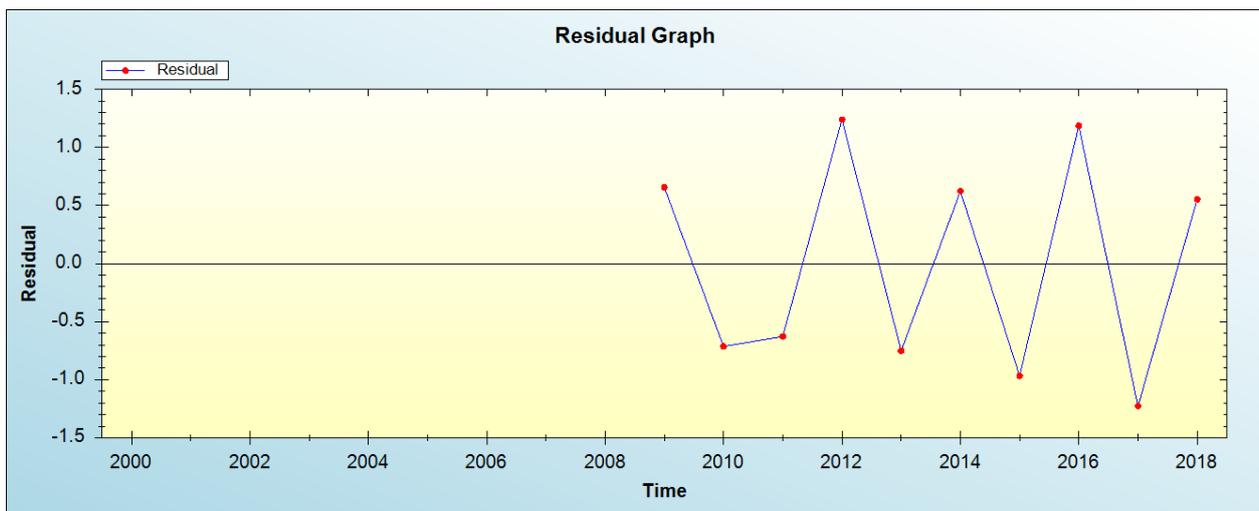*Residual Analysis for the ANN model*

Figure 1: Residual analysis
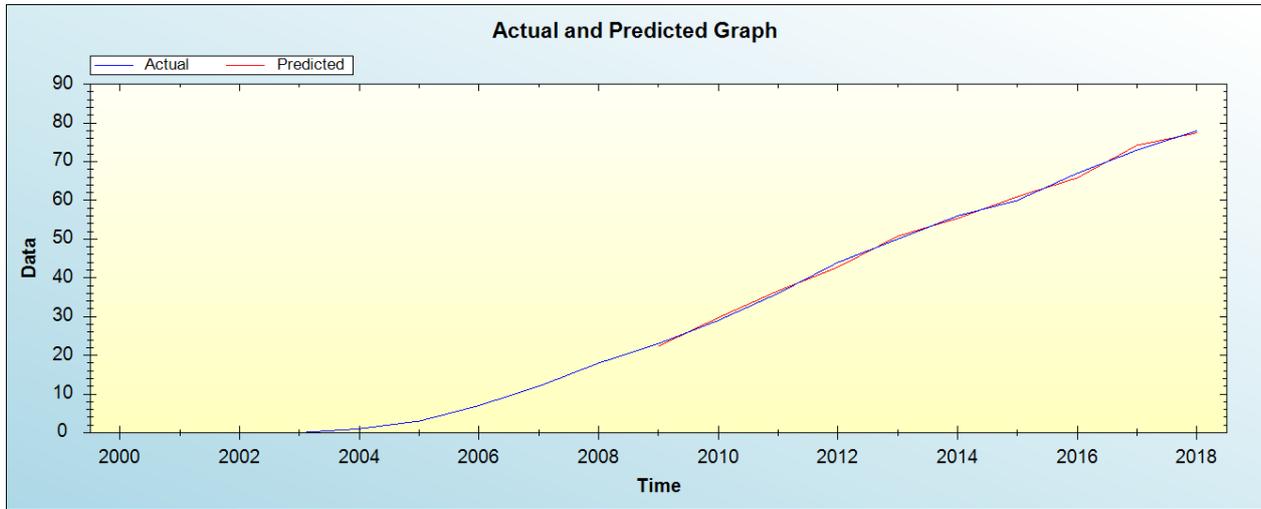
In-sample Forecast for M

Figure 2: In-sample forecast for the M series

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

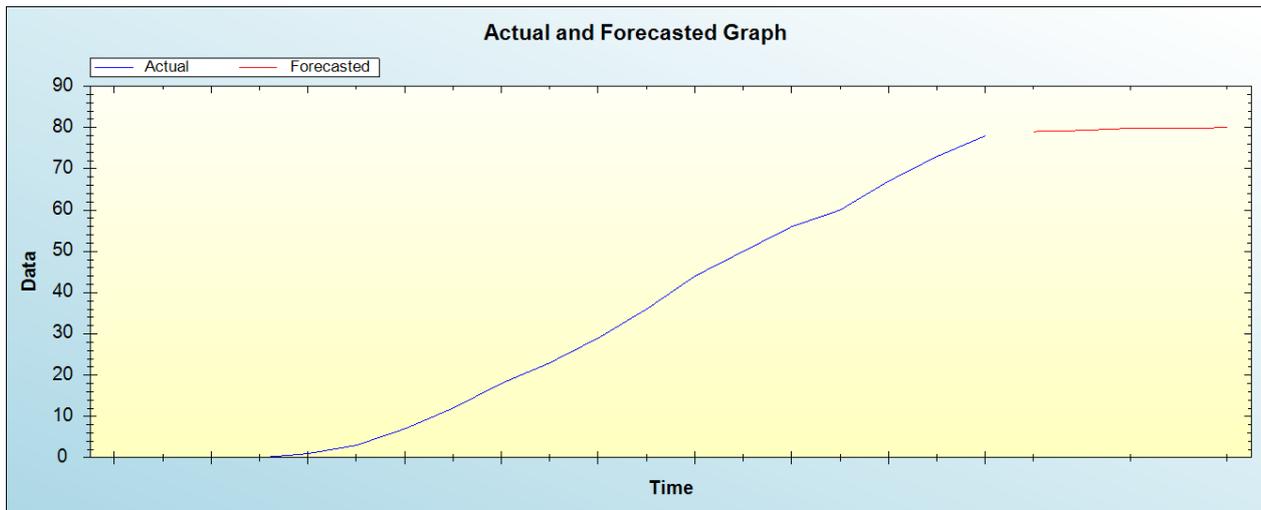*Out-of-Sample Forecast for M: Actual and Forecasted Graph*

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

Out-of-Sample Forecast for M: Forecasts only

Table 3: Tabulated out-of-sample forecasts

Year	Forecasted ART coverage
2019	79.0305
2020	79.3071
2021	79.8519
2022	79.8538
2023	80.0097

Over the study period, the minimum and maximum ART coverage was 0 and 78 % respectively. There was zero reported ART coverage for the period 2000-2003 because National ART program was rolled out in 2004. The average ART coverage over the study period was 29.3 .The data utilized in this study is positively skewed with an excess kurtosis of -1.3047 meaning that the data is not normally distributed. The residual graph and model evaluation criteria (Error, MSE, MAE) indicate that the model is

stable and suitable for forecasting ART coverage in Malawi. Figure 3 shows that the applied ANN (9,12,1) model simulates observed data very well. The neural network model predicted that will slightly increase in the out of sample period and will be around 80 %.

V. CONCLUSION & RECOMMENDATIONS

Malawi's ART program has been a success as the country recorded an upward trend in ART coverage over the period 2000-2018. This clearly shows the government's commitment in the provision of Antiretroviral therapy to all the people living with HIV. The neural network model predicts that the country is likely to have a slight increase in ART coverage over the period 2019-2023. This is commendable and therefore the authorities are encouraged to increase HIV testing capacity, strengthen TB/HIV collaboration and strengthen the system of tracking loss to follow up ART patients.

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