

Modelling and Forecasting Child Immunization against Measles Disease in Burkina Faso Using Artificial Neural Networks (ANN)

¹Mr. Takudzwa. C. Maradze, ²Dr. Smartson. P. NYONI, ³Mr. Thabani NYONI

¹Independent Researcher, Harare, Zimbabwe

²ZICHIRE Project, University of Zimbabwe, Harare, Zimbabwe

³SAGIT Innovation Center, Harare, Zimbabwe

Abstract - In this research paper, the ANN approach was applied to analyze child immunization trends in Burkina Faso. The employed data covers the period 1985 – 2020 and the out-of-sample period ranges over the period 2021 – 2025. The residuals and forecast evaluation criteria (Error, MSE and MAE) of the applied model indicate that the model is quite stable. The results of the study indicate that it is possible to win the war against the scourge of measles in the country. A 3-fold policy recommendation has been suggested in order to help public health policy makers in controlling the disease in the country.

Keywords: ANN, Forecasting, Measles Disease.

I. INTRODUCTION

The World Health Organization (WHO), in 2019 noted that measles is a highly infectious disease associated with complications such as pneumonia, diarrhea, or encephalitis in approximately 30% of cases and case fatality ratios (CFRs) as high as 5–10% in developing countries. It went on to allude that this infectious disease is caused by a virus, which usually results in a high fever and rash, and can lead to blindness, encephalitis or death, (WHO, 2019). (WHO) and the United Nations Children's Fund (UNICEF) notes that measles is a global public health problem which causes morbidity and mortality, estimates done showed that 1.5 million children worldwide continue to die from vaccine-preventable diseases like measles every year because of sub-optimal vaccination coverage, (WHO, 2019). The largest number of these deaths occurs in Sub-Saharan Africa (SSA) and South- East Asia, examples of such countries are Burkina Faso which is situated in SSA, Black et al (2010). 70% of unvaccinated children worldwide live in these regions, (WHO, 2017). With such reports this displays the need for continued modelling and monitoring of vaccination programme performance to detect potential problem and to identify appropriate solutions in these regions. Kagoné et al (2017), notes that childhood vaccination is playing pivotal role in reducing global in morbidity and mortality. Duclos et al (2009), highlighted that childhood vaccinations are considered to be the most successful public health interventions in terms of number of deaths averted per year. To date all African countries are implementing the WHO Expanded Programme on Immunization (EPI), its aim is to deliver a complete number of antigens for six killer diseases that affect newly born children in a timely, safe, and effective way to all children and women. A well-performing vaccination programme should obtain high and equitable coverage for all antigens, Kagoné et al (2017). In Burkina Faso despite joining the EPI and other vaccination schemes, it has been experiencing periodic measles outbreaks with the last and large outbreak being in 2009, Kidd et al (2012). Research has been emphasized on the need to be able to better address subtleties of measles transmission dynamics, such as age-specific attack rates and population immunity, that offer an extended herd effect at the local, national, regional, and global level. With expanded efforts of measles control adopted in Burkina Faso, reliable estimates of disease burden are becoming increasingly important, to help guide policy planning and vaccine strategies.

1.1 Relevance of the Study

Measles is both endemic and epidemic throughout the world, and therefore, it is difficult to quantify global disease burden at any one time, Miller A (2000). Although the World Health Organization (WHO) receives reports of measles disease from ministries of health through regional offices, these frequently represent an underestimation of the true incidence. This can be attributed to the different quantifying and reporting techniques different ministries of health use, hence no simple extrapolation techniques to quantify global disease burden. Clinically diagnosed measles cases have been reportable to the Burkina Faso MOH since 1984, S. Kidd et al (2012). Reports from WHO (2019), show that the greatest documented measles epidemic in Burkina

Faso occurred in 1996 and that annual outbreaks cases occurred, during 1997–2005 with peak transmissions during January–June each year. In the year 2007, cases decreased to a historic low of 150 cases. However, in 2008, cases increased to 1762 and transmission continued thru the year and into 2009. The concern over the increase in measles cases and the possible consequences necessitated an investigation into the prevalence of measles in Burkina Faso post that period. Prior to this study, no investigation had been done to establish the trend in measles cases or how immunization is being managed. Results of the study will be used to inform the government of Burkina Faso, WHO and UNICEF ensure measles control and prevent future outbreaks. Derived data will also help ensure improved strategies for identifying and reaching unvaccinated children and for reducing missed opportunities for vaccination are needed to continue the region’s progress in measles mortality reduction.

II. RELATED STUDIES

In related studies, S. Kidd et al (2012), carried out a study in Burkina Faso to investigate the 2009 measles outbreak and further describe the pandemic and the risk factors associated with it. A case control study was undertaken and the results showed that vaccination was the main risk factor in all three geographical located regions. Schoeps et al (2013), carried out a study to identify the timely vaccination among young children in North-West Burkina Faso, using a multivariable ordinal logistic regression. Findings were that mothers’ education, season of birth, socio-economic status, and area of residence were significantly linked with failure of timely adherence to the complete immunization schedule. From August to December 2011, the GAVI Alliance carried out mathematical modeling the impact of vaccination in 73 countries, Burkina Faso included. They estimated that routine and supplementary immunization activities with measles vaccine were expected to avert an additional 13.4 million deaths. Estimated figures of deaths avoided per 1000 persons immunized were highest for first-dose measles (16.5). Ferrari et al (2013), used Dynamic models to assess the prevalence of developing countries. He found out that while classic predictions do hold in general, the impact of vaccination on the age distribution of cases and stochastic fadeout are mediated by local birth rate. Other results from the dynamic models predicted that vaccinations should increase the mean age of infection and increase inter-annual variability in incidence. Kagone et al (2012), did a study in rural Burkina Faso to assess the factors associated with adherence to the vaccination schedule using a binomial regression to derive prevalence ratios (PRs) in univariate and multivariate regression models. Results were that the coverage was significantly lower in urban than in rural areas and that vaccination coverage was neither influenced by sex nor influenced by place of birth or by maternal factors. Verguet et al (2015), estimated optimal scheduling of Supplemental Immunization Activities SIAs in countries with the highest measles burden. Results showed that regular SIAs at high coverage levels are a viable strategy to prevent measles outbreaks.

III. METHODOLOGY

Fischer & Gopal (1994), underscore that no stringent rules exist for the determination of the ANN structure, hence this paper applies the popular ANN (12, 12, 1) model based on the hyperbolic tangent activation function. This paper applies the Artificial Neural Network (ANN) approach in predicting sexual assault cases at GNH.

3.1 Data Issues

This study is based on annual observations (that is, from 1985 – 2020) of the country’s rate of child immunization against measles [denoted as K]. According to the World Bank (2021), child immunization, measles, measures the percentage of children ages 12-23 months who received the measles vaccination before 12 months or at any other time. A child is considered adequately immunized against measles after receiving one dose of vaccine. Out-of-sample forecasts will cover the period 2021 – 2025. All the data was gathered from the World Bank online database.

IV. FINDINGS OF THE STUDY

ANN Model Summary

Table 1: ANN model summary

Variable	K
Observations	24 (After Adjusting Endpoints)
Neural Network Architecture:	
Input Layer Neurons	12
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	0.023766
MSE	0.854227
MAE	0.570904

Residual Analysis for the Applied Model

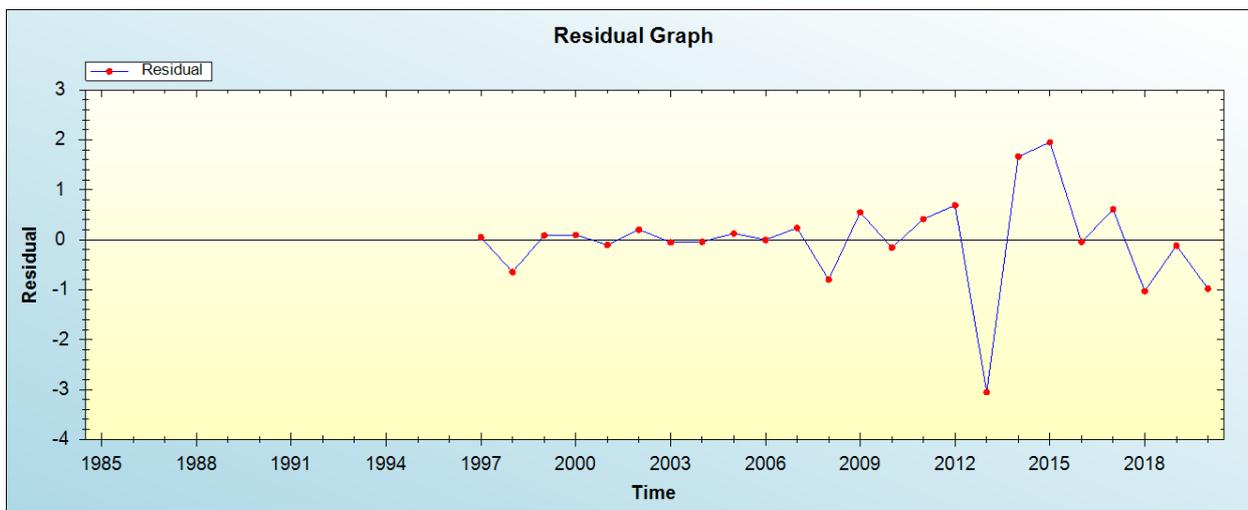


Figure 1: Residual analysis

In-sample Forecast for K

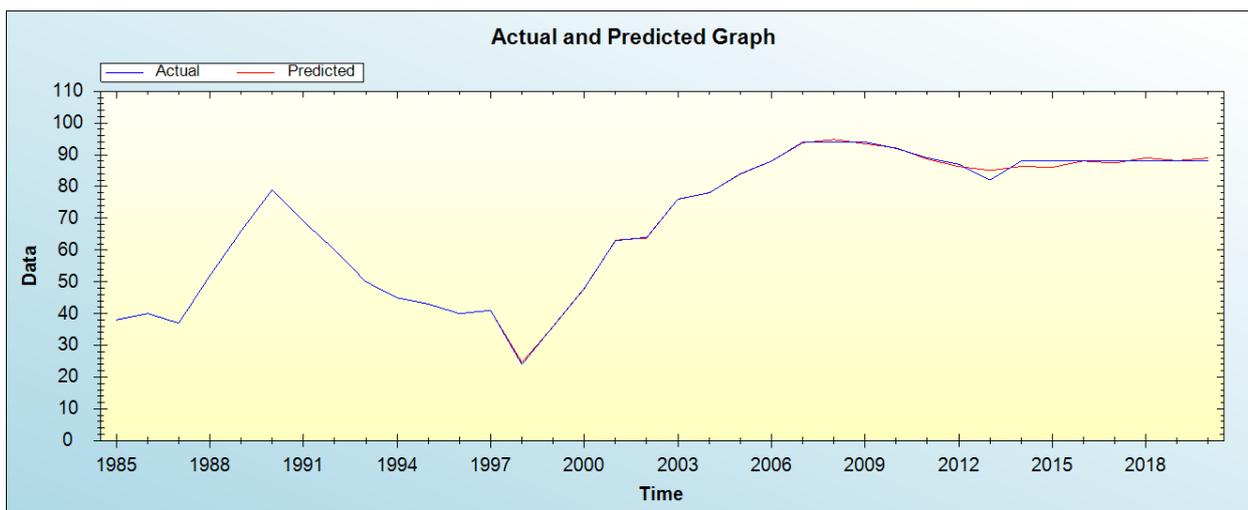


Figure 2: In-sample forecast for the K series

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

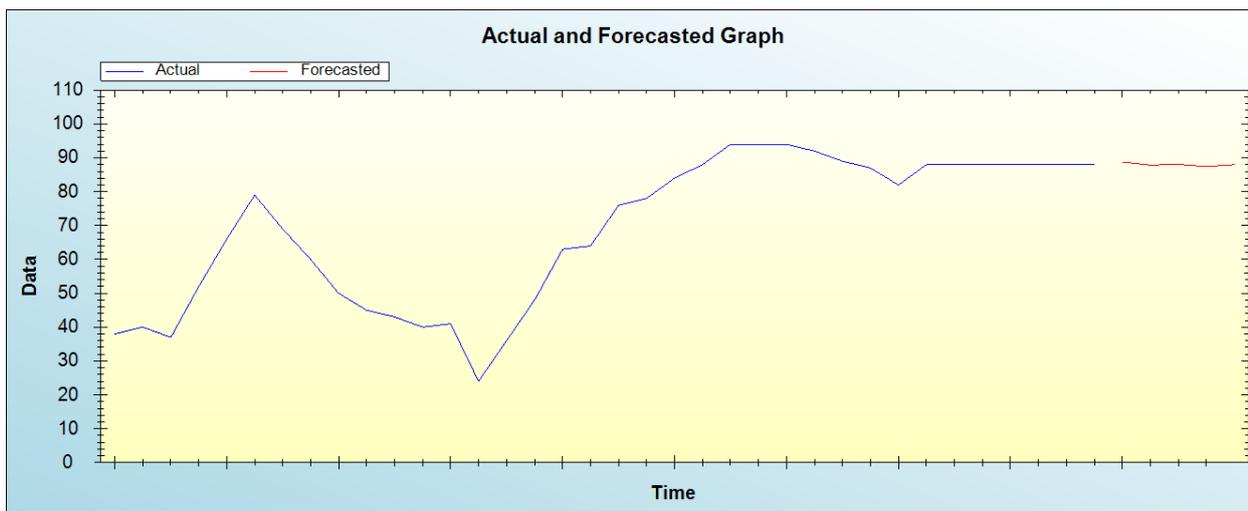


Figure 3: Out-of-sample forecast for K: actual and forecasted graph

Out-of-Sample Forecast for K: Forecasts only

Table 3: Tabulated out-of-sample forecasts

Year	Forecasts
2021	88.7711
2022	87.8514
2023	88.0641
2024	87.4298
2025	87.9944

The applied is stable as shown in table 1 and figure 1. The forecasts indicate that child immunization against measles in the country would be around 88% over the next 5 years.

V. CONCLUSION AND POLICY RECOMMENDATIONS

According to the Gavi vaccine alliance, Burkina Faso is one of the African states with the highest vaccination coverage rates and managing to successfully use immunization as a means to deliver other health services. The country’s experience shows that great strides may be achieved through what can be done through high-level political support and stakeholders’ collaborations across the health sector. Recommendations highlighted in this paper are to cement the already executed decisions being made, these include:

- i. The government is encouraged to continually allocate funds to the health sector that allow harnessing donor immunization programmes, however this should be to a lower extent and focus be put on developing nationally owned immunization programs
- ii. The ministry of health is encouraged to carry out campaigns and health promotion initiatives that ensure that both rural and urban children get vaccinated on time.
- iii. Giving stronger emphasis to the life-cycle approach to immunization and avoid once off doses or wait for donors, initiatives to complete the vaccine cycle should be initiated.

REFERENCES

[1] Miller, Mark A. "Introducing a novel model to estimate national and global measles disease burden." *International journal of infectious diseases* 4, no. 1 (2000): 14-20.

- [2] World Health Organisation. Fact sheet: immunization coverage [cited 2021 Jan 20] Available from: <http://www.who.int/mediacentre/factsheets/fs378/en/>.
- [3] Black RE, Cousens S, Johnson HL, et al. Global, regional, and national causes of child mortality in 2008: a systematic analysis. *Lancet*. 2010; 375:1969–1987.
- [4] World Health Organisation. Vaccination recommendations. [cited 2021 Jan 24]. Available from: http://www.who.int/immunization/policy/Immunization_routine_table1.pdf
- [5] Kagoné, Moubassira, Maurice Yé, Eric Nébié, Ali Sie, AnjaSchoeps, HeikoBecher, Olaf Muller, and AneBaerentFisker. "Vaccination coverage and factors associated with adherence to the vaccination schedule in young children of a rural area in Burkina Faso." *Global health action* 10, no. 1 (2017): 1399749.
- [6] Duclos, Philippe, Jean-Marie Okwo-Bele, Marta Gacic-Dobo, and Thomas Cherian. "Global immunization: status, progress, challenges and future." *BMC international health and human rights* 9, no. 1 (2009): 1-11.
- [7] Kidd, Sarah, Bassirou Ouedraogo, Chantal Kambire, Jean LudovicKambou, Huong McLean, Preeta K. Kutty, Serigne Ndiaye et al. "Measles outbreak in Burkina Faso, 2009: a case–control study to determine risk factors and estimate vaccine effectiveness." *Vaccine* 30, no. 33 (2012): 5000-5008.
- [8] Schoeps, A., N. Ouedraogo, M. Kagone, A. Sie, O. Müller, and H. Becher. "Socio-demographic determinants of timely adherence to BCG, Penta3, measles, and complete vaccination schedule in Burkina Faso." *Vaccine* 32, no. 1 (2013): 96-102.
- [9] Lee, Lisa A., Lauren Franzel, Jessica Atwell, S. Deblina Datta, Ingrid K. Friberg, Sue J. Goldie, Susan E. Reef et al. "The estimated mortality impact of vaccinations forecast to be administered during 2011–2020 in 73 countries supported by the GAVI Alliance." *Vaccine* 31 (2013): B61-B72.
- [10] Ferrari, Matthew Joseph, Bryan T. Grenfell, and P. M. Strebel. "Think globally, act locally: the role of local demographics and vaccination coverage in the dynamic response of measles infection to control." *Philosophical Transactions of the Royal Society B: Biological Sciences* 368, no. 1623 (2013): 20120141.
- [11] Verguet, Stéphane, Mira Johri, Shaun K. Morris, Cindy L. Gauvreau, Prabhat Jha, and Mark Jit. "Controlling measles using supplemental immunization activities: a mathematical model to inform optimal policy." *Vaccine* 33, no. 10 (2015): 1291-1296.

Citation of this Article:

Mr. Takudzwa. C. Maradze, Dr. Smartson. P. NYONI, Mr. Thabani NYONI, "Modelling and Forecasting Child Immunization against Measles Disease in Burkina Faso Using Artificial Neural Networks (ANN)" Published in *International Research Journal of Innovations in Engineering and Technology - IRJIET*, Volume 5, Issue 3, pp 487-491, March 2021. Article DOI <https://doi.org/10.47001/IRJIET/2021.503082>
