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Modelling and Forecasting Immunization against Measles Disease in Chad Using Artificial Neural Networks (ANN)

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***Abstract* - In this research article, the ANN approach was applied to analyze child immunization rate in Chad. The employed annual data covers the period 1984-2019 and the out-of-sample period ranges over the period 2020-2030. The residuals and forecast evaluation criteria (Error, MSE and MAE) of the applied model indicate that the model is quite stable. The ANN (12, 12, 1) model projections suggest that child immunization against measles in Chad is likely to range between 39% and 59% per year over the next decade. The government is encouraged to intensify child health surveillance and control programs in line with our policy recommendations.**

Keywords: Modelling, Forecasting, Artificial Neural Networks, ANN.

I. INTRODUCTION

According to the World Health Organization WHO, (2020) measles is a highly contagious, infectious disease of the respiratory system caused by a paramyxovirus. The virus infects the respiratory mucosa and is spread by droplets expelled anytime the person coughs or sneezes. WHO goes on further to state that measles is usually transmitted by direct inhalation of the airborne droplets or when someone touches an infected surface and then places fingers on the mucosa of the mouth or nose. The droplets can remain infectious after landing on surfaces for up to two hours. Between 75% and 95% of non-immune persons who are exposed to the virus become infected, and nearly all infected persons develop clinicalillness.40% of measles cases, can cause more serious complications, especially in areas where malnutrition, Vitamin A deficiency, HIV/AIDS, and other conditions that compromise the immune system are common, Le Beau A (2020). Common lifelong disabilities include brain damage and blindness, Goodson *et al* (2011). Chad is among the countries with such serious complications and has been experiencing a measles outbreak since early 2018, with the case incidence rapidly increasing since the beginning of 2019, (WHO, 2020). The country of Chad is located in Central Africa and is bordered by Sudan, Cameroon, the Central African Republic, and Nigeria. The territory spreads across 1,284,000 square kilometers of desert and rain forest. Chad is the fifth largest country in Africa and the 21st largest country in the world, with a population of15.5 million. Chad is an enormously poor country with one of the highest levels of hunger in the entire world. Approximately 66.2 percent of Chad's population is living in severe poverty. In Chad, children are required to attend school to receive an education, yet only about 68% of children attend.

The healthcare system in Chad is extremely poor. The healthcare facilities are overpopulated, under supported, and are not spread equally throughout the country. Deficits in the healthcare system are primarily due to the political uncertainty that has been a concern for many years. Before a measles vaccination was present in Africa, the measles virus mainly affected young children. Between 1970 and 1980, a measles vaccination was introduced in the African countries by the World Health Organization (WHO). The measles vaccination helped the countries significantly, leading to longer times between epidemics. However, the vaccination still has not been distributed to enough children to stop annual outbreaks. Every year Chad experiences measles outbreaks. The outbreaks normally begin in the spring and die off around June, when the rainy season begins. When children are malnourished, they are more susceptible to becoming ill and suffering from the measles. Those who are malnourished have a lessened chance of surviving the disease. The response to this outbreak is being challenged by lack of resources, including testing reagents, vaccines and operational funds, (WHO, 2020). Systematic laboratory testing of specimens has not been conducted since the beginning of 2019, affecting proper description and characterization of the outbreak, Le Beau A (2020). Vaccination campaigns have also been irregular, with only half of the affected regions covered. Recent investigation by the WHO showed that more than 80% of the new cases have not been vaccinated, an indication of continuous low coverage of routine and

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supplementary immunization services. There is need to step up the ongoing response to this outbreak, especially immunization services in order to quickly contain the outbreak, the WHO statement went on to underscore. Mobilization of resources for the implementation of the response plan in all affected zones is of paramount importance. To our knowledge, only a limited number of recent studies have been published on measles mortality in Chad. To date Nwafor *et al* (2019) carried out a research on measles disease using a mathematical model to compare and contrast the exponential model, the logistic model, the SIR model. Results were that the number of susceptible, infected and vaccinated individuals is consistent with theoretical analysis. The goal of this paper is to model and forecast future measles cases in Chad and come up with information that helps policy makers and international aid enablers come up strategies that are sustainable for modelling outbreaks of measles.

II. METHODOLOGY

The Artificial Neural Network (ANN), which we intend to apply in this study; 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 any data-set to describe the nonlinear and interaction effects with great accuracy. Arguably, explicit guidelines exist for the determination of the ANN structure hence the study 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 infant mortality rates in Chad.

Data Issues

This study is based on annual rates of immunization of children against measles in Chad for the period 1984 – 2019. The out-of-sample forecast covers the period 2020 to 2030. Child immunization; for the purposes of this study, is defined as the percentage of children aged 12-23 months who received the measles vaccination in a given year. All the data employed in this paper was gathered from the World Bank.

III. FINDINGS OF THE STUDY

ANN Model Summary

Table 1: ANN model summary

Variable	J
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	0.052951
MSE	2.713797
MAE	1.207200

Residual Analysis for the Applied Model

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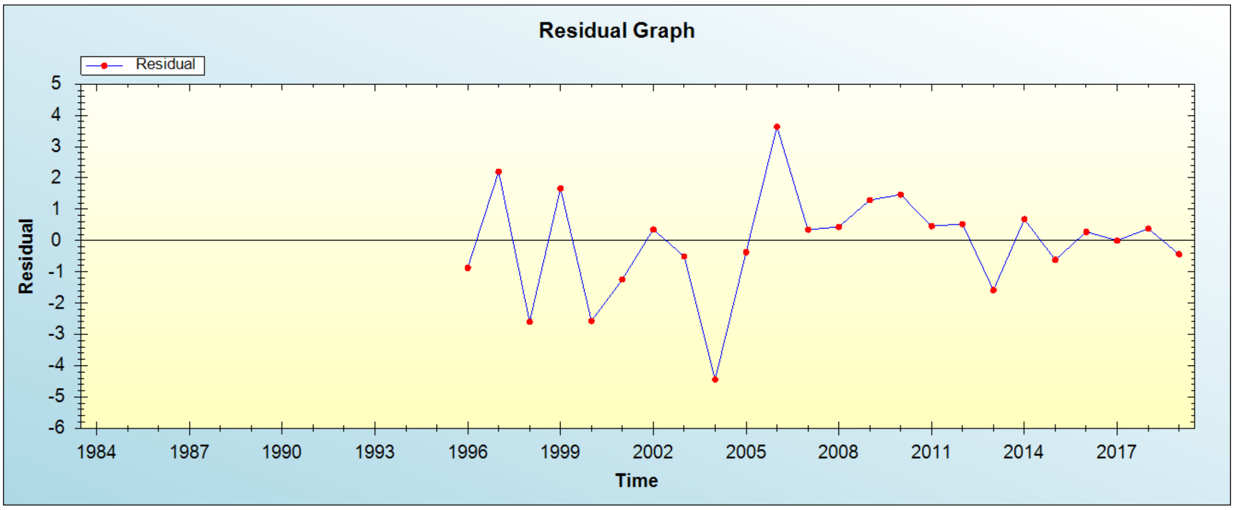

Figure 1: Residual analysis

In-sample Forecast for J

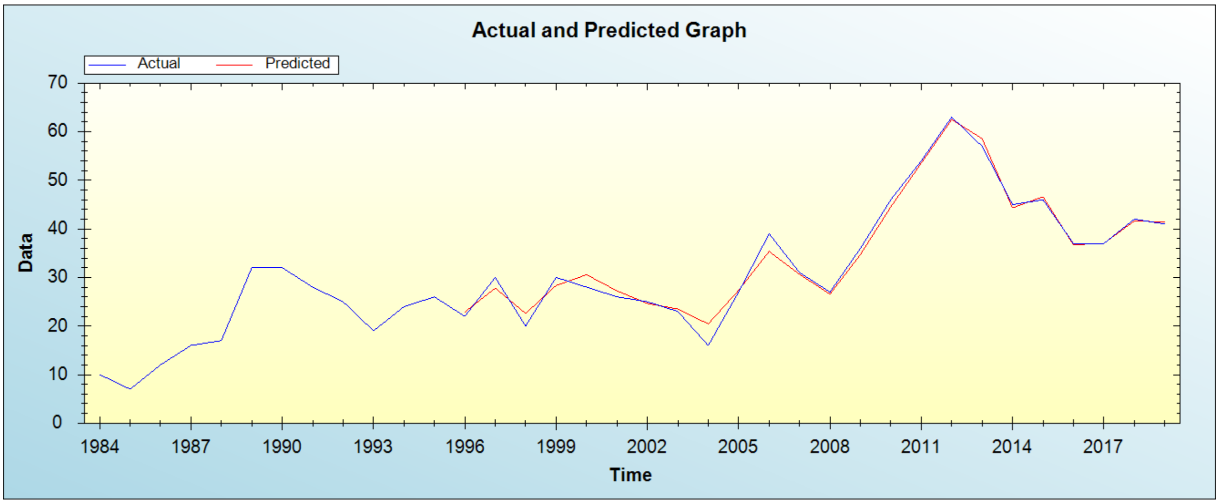

Figure 2: In-sample forecast for the J series

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

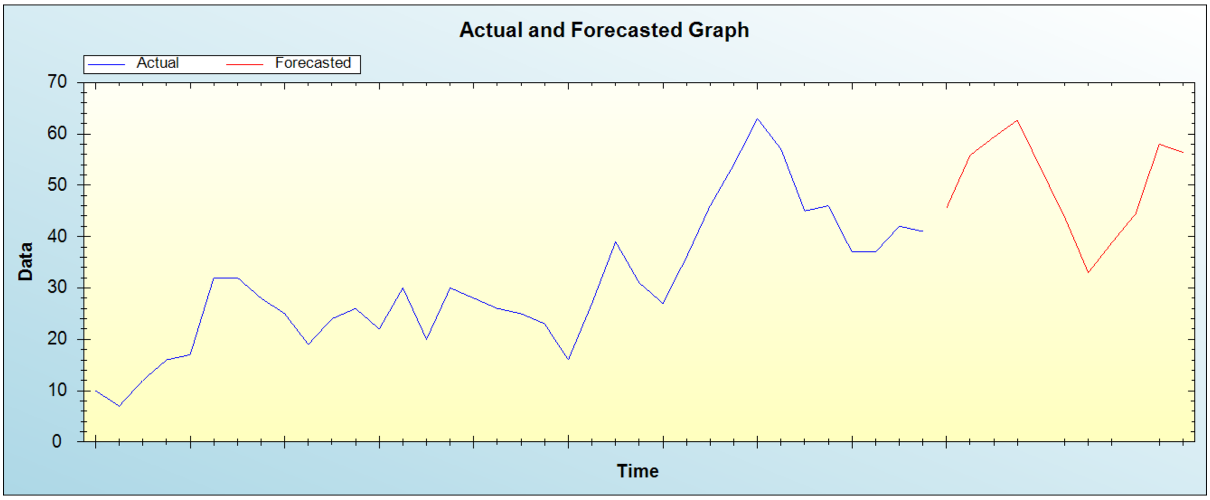

Figure 3: Out-of-sample forecast for J: actual and forecasted graph

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Out-of-Sample Forecast for J: Forecasts only

Table 3: Tabulated out-of-sample forecasts

Year	Forecasts
2020	45.5198
2021	55.8309
2022	59.3430
2023	62.6653
2024	53.1626
2025	43.7653
2026	32.9660
2027	38.8197
2028	44.4212
2029	57.9941
2030	56.3863

The main results of the study are shown in table 1. It is clear that the model is stable as confirmed by evaluation criterion as well as the residual plot of the model shown in figure 1. It is projected that child immunization against measles in Chad is likely to range between 39% and 59% per year over the next decade.

IV. CONCLUSION AND POLICY RECOMMENDATIONS

Measles deaths, unlike some other high-burden diseases in sub-Saharan Africa like malaria, tuberculosis, and HIV/AIDS, may be entirely prevented by using an effective, safe, and cheap vaccine under proven vaccination approaches. Governments, international non-governmental organizations, and international partnerships like the Measles Initiative should strengthen their efforts in countries like Chad where measles continues to kill thousands of children every year. Recognizing failures in measles vaccination and mortality lessening programs might be the primary step towards eliminating measles in Chad. There is need for reactive measles vaccination campaigns, especially in marginalized regions of Chad where most masses are illiterate and the mothers have little knowledge on the importance of their children to be immunized. Routine immunization activities should be maintained and epidemiological investigations conducted at district level, including collecting specimens and documentation of cases. This will ensure coherent research and informed forecasts that help control the measles disease. Finally, further research is needed to better understand the changing measles epidemiology in Chad especially in times of refugee influx through the borders.

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