NOVATEUR PUBLICATIONS
JournalNX- A Multidisciplinary Peer Reviewed Journal
ISSN No: 2581 - 4230
VOLUME 6, ISSUE 6, June -2020

# MODELING AND FORECASTING NEW DIARRHOEA CASES IN UNDER-FIVES IN CHITUNGWIZA URBAN DISTRICT, ZIMBABWE: EMPIRICAL EVIDENCE FROM A BOX-JENKINS "CATCH ALL" MODEL

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**ABSTRACT:**

**In this paper, the Artificial Neural Network model has been employed to project diarrhoea cases in children under five years of age in Chitungwiza urban district in Zimbabwe. The study covers the period January 2012 to December 2018. The out-of-sample forecasts range over the period January 2019 to December 2020. The residual analysis of the model indicates that the model applied in this research article is stable and suitable for forecasting under 5 diarrhoea cases in Chitungwiza urban district. The forecasts show a generally downwards trajectory of diarrhoea cases in Chitungwiza urban district over the period January 2019 – December 2020. Amongst other recommendations, there is need for the relevant authorities to strengthen sanitation and hygienic practices in Chitungwiza urban district.**

## INTRODUCTION:

Diarrhoea in children under five years of age remains a challenge in reducing child mortality (Li et al., 2020; Sharma et al., 2020). Diarrhoea is the passage of three or more loose or liquid stools per day or more frequent than is normal for the individual (WHO, 2015). Children are affected by diarrhoea mainly due to poor environmental sanitation and hygiene, inadequate water supplies and poverty (Boschi-Pinto et al., 2008). Transmission agents that cause diarrhoea are usually by the faecal oral route, which include the ingestion of faecal contaminated water or food, person to person contact and direct contact with infected faeces (Andu et al., 2002). In Zimbabwe, diarrhoea remains an annual affair, especially in Chitungwiza where activities of street food vendors have an important role to play in the sense that they improperly handle food by contaminating it with the pathogen which is of faecal origin, especially when considering the fact that most of the street food vendors are not formerly trained in food handling and preparation (Nyoni & Bonga, 2019).

Cases of diarrhoea have long term complications like malnutrition, growth retardation and immune impairment (Nwaoha et al., 2016). There are an estimated 1.7 billion cases of diarrhoea with an average of 2.9 episodes/child/year, and an estimated 1.87 million deaths among children under five years (Brown et al., 2013). The burden of diarrheal diseases among children is by far more in low and middle-income countries where it is the second leading cause of deaths in children under 5 years (Nsabimana et al., 2017). Africa and South-East Asia regions have 78% of diarrheal deaths among children less than five years (Boschi-Pinto et al., 2008). Most deaths from diarrhoea among children occur in Africa, where diarrhoea is the largest cause of death among children under five years of age and also a major cause of childhood illness (Black et al., 2003; Walker et al., 2012).

Controlling diarrhoea has been on the public health agenda for so long (Sharma et al., 2020). Thus, an accurate forecast of diarrhoea cases in children under the age of five; is essential for public health authorities to clearly understand the characteristics of the epidemic and consequently formulate and implement relevant policy actions, such as disease surveillance and deployment of emergency supplies. According to the UNICEF (2016), healthy children are the foundation of robust economies and thriving communities; they are the lifeblood of sustainable development. With increased investment from the government of Zimbabwe and its partners, the city of Chitungwiza can win in the war against diarrhoea in children; contributing to the attainment of the Sustainable Development Goals (SDGs), particularly goal number 3 of ending preventable child deaths.

## OBJECTIVES OF THE STUDY:

i. To assess diarrhoea cases in children below five years of age in Chitungwiza urban district over the period January 2012 – December 2018.
ii. To forecast diarrhoea cases for Chitungwiza urban district over the period January 2019 – December 2020.
iii. To determine whether diarrhea cases are trending upwards or downwards for Chitungwiza urban district over the out-of-sample period.

## Statement of the Problem:

Diarrhoea is the second leading cause of death among children under five years old in the world, affecting approximately 1.5 million children per year (Masukawa et al., 2014) with more than 800000 under-fives kicking the bucket each year (Tambe et al., 2015; Acharya et al., 2018). It actually contributes approximately 8% of deaths among children between one and 59 months which is more than numbers recorded for Acquired Immune Deficiency Syndrome (AIDS), malaria and measles combined (UN IGME, 2017). In many developing countries such as Zimbabwe, diarrhoea is the leading cause of morbidity and mortality among children. Every child aged below five years of age in these developing countries experiences five incidents of diarrhoea each year (Tambe et al., 2015). Chitungwiza, just like any other urban centre in the country, is haunted by an inadequate water supply. The already bad situation is compounded by poor sanitation and hygiene that has characterized literally the whole country. Due to fast growing urbanization, this phenomenon has become express “express” in Chitungwiza urban district (Nyoni & Nyoni, 2020). What are the dynamics of diarrhea cases in Chitungwiza urban district?

## Relevance of the Study:

Young age contributes to children’s vulnerability to diarrhoeal diseases (Oloruntoba et al., 2015). In fact, children under five years old are more vulnerable to diarrhoeal diseases than older members of the family as they tend to have lower immunity (Baldwin, 2013; Ikeda et al., 2019). Children are also unable to wash their hands properly to prevent the transfer of pathogens when eating (Ogunsola et al., 2013). It thus becomes inevitable to empirically reflect on the pattern of diarrhea cases that have been recorded in Chitungwiza urban district, especially for children below five years of age since they are the most susceptible group.

## LITERATURE REVIEW:

In an Ethiopian study, Regassa et al. (2008) examined environmental determinants of diarrhea among under-fives using a stepwise logistic regression model and concluded that diarrhea morbidity was a major problem in Nekemte town of Ethiopia. In a Nigerian study, Nwaoha et al (2016) investigated the prevalence of diarrhea and associated risk factors in children aged 0-5 years, at two hospitals in Umuahia in Abia and found out that the main risk factors associated with childhood diarrhea in Nigeria include kitchen cleaning, hand washing, waste disposal as well as mother's education. In Nepal, Kalakheti et al. (2016) investigated risk factors of diarrhea in children under five years using logistic regression and found out that there are a few factors affecting childhood diarrhea such as no child suffering from diarrhea in the neighborhood, there was a toilet in the house and washing hands always. In Rwanda, Nsabimana et al. (2017) looked at factors contributing to diarrheal diseases among children less than five years in Nyarugenge district using descriptive statistics and basically found out that the prevalence of diarrhea was high in Nyarugenge district compared to national level. In a South African study, Ikeda et al. (2019) analyzed climatic factors in relation to diarrhea hospital admissions in rural Limpopo, using contour analysis techniques and basically found out that children under five years of age were especially vulnerable to diarrhea during very hot, dry conditions as well as when conditions were wetter than usual. In Zimbabwe, Nyoni & Bonga (2019) investigated hygienic practices of street food vendors in Harare and found out that most street food vendors in Harare have not received any formal training in food preparation and handling, which puts the public at risk of getting diarrheal diseases.

In yet another study done in Nepal, Li et al. (2020) assessed diarrhea in children under five years of age using a spatiotemporal analysis based on demographic and health survey data, hinged on a Bayesian logistic regression model, and revealed that there is a generally decreasing diarrhea risk trend in Nepal from 2006 – 2016. In yet another Zimbabwean study, Nyoni & Nyoni (2020) applied ANN models to forecast new dysentery cases in children under 5 years of age in Chitungwiza urban district in Zimbabwe and revealed a generally downwards trajectory of new dysentery cases in children under 5 years of age. Daisy et al. (2020) developed a forecasting model (the SARIMA model) for cholera incidence in Dhaka megacity through time series climate data and found out that multi-variate SARIMA models were suitable for forecasting cholera risks in Dhaka. Most of the reviewed literature, with the exception of Daisy et al. (2020) and Nyoni & Nyoni (2020); fails to realize the importance of forecasting future cases of diarrhea in their respective study areas and yet such predictions are essential for public health policy making, especially with regards to avoiding preventable diarrheal childhood deaths. In Zimbabwe, no similar study has been done so far. This study will fill this research gap and is anticipated to go a long way in reducing diarrhea-attributable child mortality in the country.

## METHODOLOGY:

The Autoregressive Integrated Moving Average (ARIMA) model is widely used in Diarrhoea incidence prediction as a classical method (Fang et al., 2020). The seasonal ARIMA (SARIMA) model, which incorporates seasonal variation and is developed from the ARIMA model performs better than the former in the presence of a seasonal pattern (Xu et al., 2017; Tian et al., 2019). The Box – Jenkins technique is the brain-child of Box & Jenkins (1970) and in this research paper; it will be employed for analyzing new monthly Diarrhoea cases for Chitungwiza urban district in Zimbabwe. In general, a Box-Jenkins SARIMA model can be shown as follows:

$$\phi_p(B)\emptyset_p(B^S)R_t = \theta_q(B)\Theta_q(B^S)\varepsilon_t \quad \text{[1]}$$

Where B is the backshift operator, $\phi_p, \emptyset_p, \theta_q$ and $\Theta_q$ are polynomials of order p, P, q and Q respectively. $\varepsilon_t$ is a white noise process and $R_t = \nabla_d \Delta_s^D Y_t$ is the differenced R series.

**Data:**

This study is based on monthly observations of new Diarrhoea cases (R) in children below the age of five in Chitungwiza Urban District in Chitungwiza, from January 2012 to December 2018. The out-of-sample forecast ranges over the period January 2019 to December 2020. All the data employed in this study was gathered from Chitungwiza City DHIS2 system.

**Diagnostic Tests and Model Evaluation:**

Unit Root Tests: Graphical Analysis:

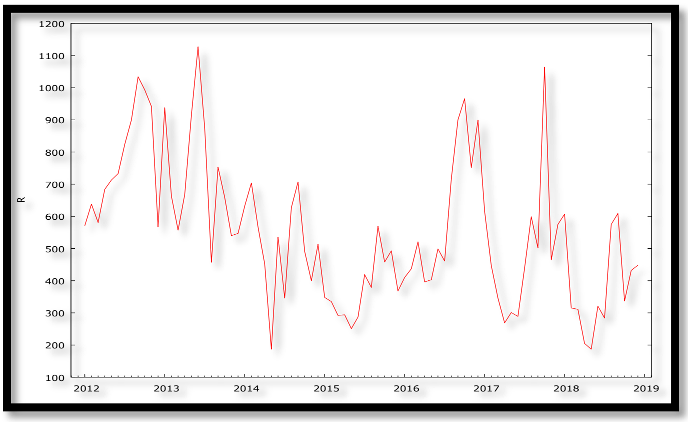



Figure 1: Graphical Analysis

Figure 1 shows that R does not follow any explicit trend, although we can generally infer that R is basically falling over the period under study. This means that diarrhoea cases in under-fives in Chitungwiza Urban District have been decreasing over time, though slowly. Hence, it is reasonable to suspect that R could be a non-stationary series. Hence, there is need to carry out a confirmatory formal unit root test such as the Augmented-Dickey-Fuller (ADF) test. For the 7 years under consideration; September 2012, June 2013, September 2014, September 2015, October 2016, January 2017 and January 2018 have the highest number of diarrhoea cases, that is; 1034, 1127, 707, 569, 966, 616 and 607, respectively. This leads us to the inference that there is need for seasonal differencing since seasonality appears to exist after every 12 months as generally suggested by the highest number of diarrhoea cases that tend to be experienced in September/ October/ January of almost every year under study. Therefore, the Box-Jenkins "catch all" model is apparently suitable for analyzing these diarrhoea cases.

**The ADF Test:**

Table 1: Levels-intercept

| Variable | ADF Statistic | Probability | Critical Values | | Conclusion |
|---|---|---|---|---|---|
| $R_t$ | -4.057693 | 0.0019 | -3.511262 | @1% | Stationary |
| | | | -2.896779 | @5% | Stationary |
| | | | -2.585626 | @10% | Stationary |

Table 2: Levels-trend & intercept

| Variable | ADF Statistic | Probability | Critical Values | | Conclusion |
|---|---|---|---|---|---|
| $R_t$ | -4.689535 | 0.0015 | -4.072415 | @1% | Stationary |
| | | | -3.464865 | @5% | Stationary |
| | | | -3.158974 | @10% | Stationary |

Table 3: without intercept and trend & intercept

| Variable | ADF Statistic | Probability | Critical Values | | Conclusion |
|---|---|---|---|---|---|
| $R_t$ | -1.143433 | 0.2285 | -2.593468 | @1% | Not stationary |
| | | | -1.944811 | @5% | Not stationary |
| | | | -1.614175 | @10% | Not stationary |

Table 4: 1st Difference-intercept

| Variable | ADF Statistic | Probability | Critical Values | | Conclusion |
|---|---|---|---|---|---|
| $D(R_t)$ | -12.46904 | 0.0001 | -3.512290 | @1% | Stationary |
| | | | -2.897223 | @5% | Stationary |
| | | | -2.585861 | @10% | Stationary |

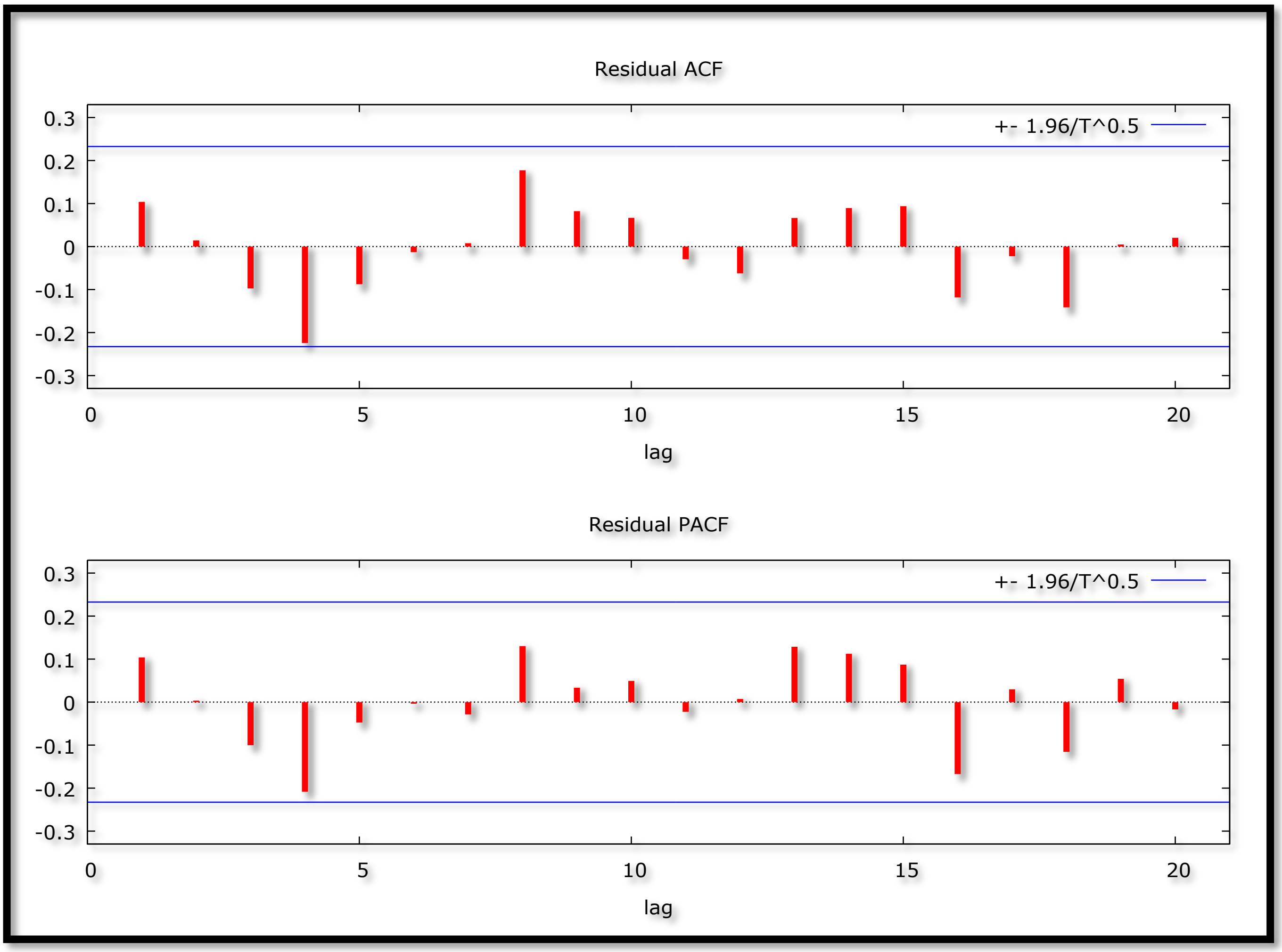
Table 5: 1st Difference-trend & intercept

| Variable | ADF Statistic | Probability | Critical Values | | Conclusion |
|---|---|---|---|---|---|
| $D(R_t)$ | -12.39091 | 0.0000 | -4.073859 | @1% | Stationary |
| | | | -3.465548 | @5% | Stationary |
| | | | -3.159372 | @10% | Stationary |

Table 6: 1st Difference-without intercept and trend & intercept

| Variable | ADF Statistic | Probability | Critical Values | | Conclusion |
|---|---|---|---|---|---|
| $D(R_t)$ | -12.54423 | 0.0000 | -2.593468 | @1% | Stationary |
| | | | -1.944811 | @5% | Stationary |
| | | | -1.614175 | @10% | Stationary |

Tables 1 – 6 basically indicate that R is an I(1) variable, hence; it is acceptable to proceed and estimate the Box-Jenkins "catch all" model.




Analysis of the Residuals of the SARIMA (0, 1, 1)(0, 1, 1)$_{12}$ Model
Residual Correlogram of the SARIMA (0, 1, 1)(0, 1, 1)$_{12}$ Model
Figure 2: Residual Correlogram

Figure 2 indicates that the residuals of the Box-Jenkins "catch all" model are indeed stable and this is proof that our predictive model is adequate.

## RESULTS OF THE STUDY:

### Descriptive Statistics:

Table 7: Summary Statistics, using the observations 2012:01 - 2018:12, for the variable R (84 valid observations)

| Mean | Median | Minimum | Maximum |
|---|---|---|---|
| 552.79 | 528.50 | 187.00 | 1127.0 |
| Std. Dev. | C.V. | Skewness | Ex. kurtosis |
| 222.58 | 0.40265 | 0.60831 | -0.29270 |

Table 7 shows that the minimum number of Diarrhoea cases in under-fives in Chitungwiza Urban District is 187 and this was recorded in May 2014 while the maximum number of Diarrhoea cases is 1127 and was recorded in June 2013. Over the study period, the average number of Diarrhoea cases recorded is approximately 553 Diarrhoea cases per month. This is unacceptably high! Responsible authorities in Chitungwiza Urban District have a role to play in reducing diarrhoeal cases in children under the age of five.

### Results Presentation:

Table 8: Main Results of the SARIMA (0, 1, 1)(0, 1, 1)$_{12}$ Model

The SARIMA (0, 1, 1)(0, 1, 1)$_{12}$ model can be presented as follows:

$$(1 - B)(1 - B^{12})R_t = (1 - 0.573585B)(1 - 0.799349B^{12})\varepsilon_t \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots [2]$$

| Variable | Coefficient | Standard Error | z | p-value |
|---|---|---|---|---|
| $\theta_q$ | -0.573585 | 0.0865521 | -6.627 | 0.0000*** |
| $\Theta_q$ | -0.799349 | 0.214571 | -3.725 | 0.0002*** |

### Forecast Graph:

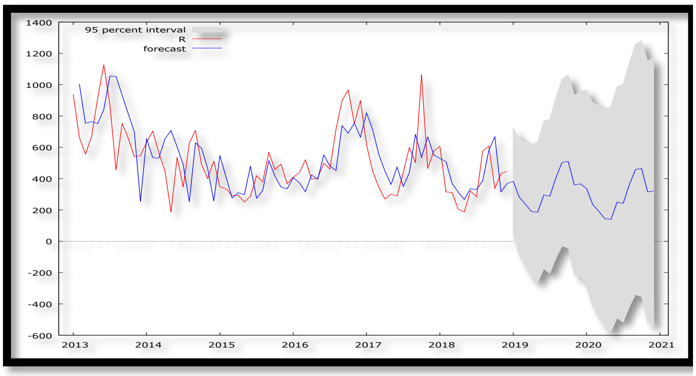
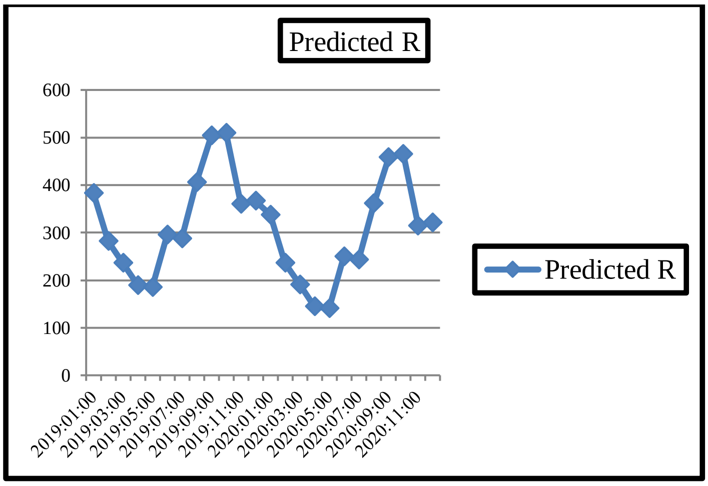



Figure 3: Forecast Graph

### Out of Sample Forecasts:

Table 9: Out-of-sample forecasts

| Year: Month | Forecasts | Standard Error | 95% Confidence Interval |
|---|---|---|---|
| 2019:01 | 382.893 | 174.096 | (41.6707, 724.114) |
| 2019:02 | 281.583 | 189.263 | (-89.3662, 652.532) |
| 2019:03 | 235.999 | 203.302 | (-162.466, 634.464) |
| 2019:04 | 189.881 | 216.432 | (-234.318, 614.080) |
| 2019:05 | 185.857 | 228.810 | (-262.602, 634.317) |
| 2019:06 | 295.464 | 240.552 | (-176.009, 766.937) |
| 2019:07 | 287.753 | 251.747 | (-205.661, 781.168) |
| 2019:08 | 406.589 | 262.464 | (-107.832, 921.009) |
| 2019:09 | 503.677 | 272.761 | (-30.9247, 1038.28) |
| 2019:10 | 510.289 | 282.683 | (-43.7599, 1064.34) |
| 2019:11 | 360.379 | 292.269 | (-212.457, 933.215) |
| 2019:12 | 366.457 | 301.550 | (-224.569, 957.483) |
| 2020:01 | 337.606 | 320.703 | (-290.959, 966.172) |
| 2020:02 | 236.296 | 332.859 | (-416.094, 888.687) |
| 2020:03 | 190.712 | 344.586 | (-484.664, 866.089) |
| 2020:04 | 144.595 | 355.927 | (-553.010, 842.199) |
| 2020:05 | 140.571 | 366.918 | (-578.575, 859.717) |
| 2020:06 | 250.177 | 377.589 | (-489.884, 990.239) |
| 2020:07 | 242.467 | 387.967 | (-517.934, 1002.87) |
| 2020:08 | 361.302 | 398.074 | (-418.909, 1141.51) |
| 2020:09 | 458.391 | 407.931 | (-341.139, 1257.92) |
| 2020:10 | 465.003 | 417.555 | (-353.390, 1283.40) |
| 2020:11 | 315.093 | 426.963 | (-521.739, 1151.92) |
| 2020:12 | 321.171 | 436.167 | (-533.701, 1176.04) |




Graphical Presentation of the Predicted Monthly Diarrhoea Cases in Under-fives in Chitungwiza Urban District (Out-of-Sample)

Figure 4: Graphical presentation of out-of-sample forecasts

Table 8 shows the main results of the SARIMA (0, 1, 1)(0, 1, 1)$_{12}$ model. Striking to note is that all the parameter estimates are statistically significant at 1% level of significance. Figure 3 and 4 as well as table 9 display the out-of-sample forecasts of the predicted diarrhoea cases in under-fives in Chitungwiza urban district. It is clear that the predicted trend is generally following a downwards trajectory, although quite slowly. Another striking feature of the prediction is that the diarrhoea cases will be highest in the months of September and October each year in the out-of-sample. This simply means that diarrhoea cases in children under five years of age in Chitungwiza urban district have a seasonal pattern hat repeats in every September and October of each year. The results of this research are consistent with Nyoni & Nyoni (2020) who also found out that dysentery cases in under-fives in Chitungwiza urban district are declining over the period January 2019 – December 2020. Just like diarrhoea, dysentery is also attributable to erratic water supplies, poor hygienic practices and inadequate sanitation. These results are also consistent Ikeda et al. (2019) who empirically verified that dry conditions are associated with diarrhea in children under five years of age in the sense that such conditions may lead to increased water storage, thus raising the risks of water contamination.

**RECOMMENDATIONS:**

i. There is need to strengthen sanitation and hygienic practices at Chitungwiza urban district.
ii. Chitungwiza city authorities should see to it that they improve access to safe water for Chitungwiza residents, for example, through drilling additional boreholes as well as repairing and maintaining existing ones.
iii. The government of Zimbabwe, through the Ministry of Health and Child Care, should provide adequate medical supplies at public health institutions in Chitungwiza for the management of diarrhea cases in the city.

**CONCLUSION:**

In Zimbabwe, diarrhoea remains one of the leading causes of preventable death, especially in children under the age of five and yet there is limited research on childhood diarrhoea. This study examined the dynamics of diarrhoea cases in children under 5 years of age in Chitungwiza urban district using ANN models. The study is new in the case of Zimbabwe and is envisioned to go a long way sensitizing the need for better health service delivery, especially by the City of Chitungwiza Health Department. The results are not surprising but rather encouraging because they point to the possibility of Chitungwiza urban district winning in the fight against diarrhoea.

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