FORECASTING COVID-19 CASES IN ZIMBABWE USING ARTIFICIAL NEURAL NETWORKS

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ABSTRACT

Caused by a deadly novel coronavirus, COVID-19 has mercilessly played havoc on many countries worldwide and Zimbabwe is one of the many countries that were not able to escape from this pandemic. Today, people in Zimbabwe; just like the rest of the world, continue to live in restricted environments in order to prevent exposure to this highly infectious disease. In this paper, the Artificial Neural Network (ANN) approach was used to model and forecast daily COVID-19 cases in Zimbabwe. The employed data covers the period March 20, 2020 to December 10, 2020 and the out-of-sample period ranges over the period December 11, 2020 to April 29, 2021. The residuals and forecast evaluation criteria (Error, MSE and MAE) of the applied model reveal that the model is indeed stable in forecasting COVID-19 daily new infections in Zimbabwe. The results of the study indicate that the country is likely to record between 0-330 new cases per day over the period 11 December 2020 to 29 April 2021. Policy makers and relevant public health authorities in the country are encouraged to continue enforcing control and preventive measures such as mass-media sensitization, social distancing, face-mask wearing, contact tracing, disinfection and decontamination of infected areas, washing and sanitization of hands and so on as advised by the WHO. These measures will help a lot in avoiding further infections, especially; in the form of local transmission; or a second wave of infections in Zimbabwe.

Keywords: - *ANN, COVID-19, Forecasting*

INTRODUCTION

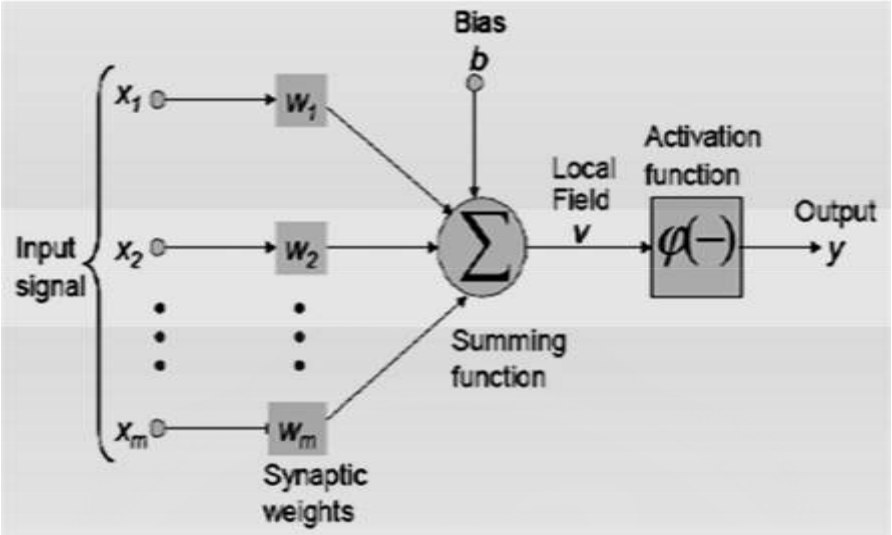
COVID-19 is a life-threatening viral disease quickly spreading its roots in literally all parts of the world (Singhal *et al*., 2020). Despite the fact that the origin of the virus is still questionable (Konarasinghe, 2020), early stages of COVID-19 have been linked to a live animal seafood market in Wuhan; pointing to a zoonotic origin of the pandemic (Chowell *et al*., 2020). Most common symptoms of COVID-19 include fever, sore throat, coughing and difficulty in breathing. The first few cases appeared in Wuhan, China, in December 2019 and then gradually, cases started coming up in many other countries as well. Today, we see that this pandemic has infected millions of people around the world (Singhal *et al*., 2020). COVID-19 has frustrated the whole world due to the fact that it is highly contagious (Fong *et al*., 2020). A single infected person will transmit the virus (usually via human-to-human transmission) with a reproduction number of approximately 1.4 to 2.5 (WHO, 2020). People infected with COVID-19 are placed in quarantine, so that the virus does not spread (Uddin *et al*., 2020) and their own immune system is expected to fight off the virus (Chan *et al*., 2020). The fatality rate is higher among the elderly, especially those aged above 60 years (WHO, 2020). However, most COVID-19 patients

experience mild to moderate respiratory illness, and they recover without requiring special treatment (Guan *et al*., 2020). COVID-19 propagation is faster when people are in close proximity. Thus, travel restrictions control the spread of the disease, and frequent hand washing is always recommended to prevent potential viral infections (Alazab *et al*., 2020). So far there is no vaccine against this deadly and highly infectious disease (Chakraborty & Maity, 2020). The first case of COVID-19 in Zimbabwe was officially reported on March 20, 2020, in the resort town of Victoria Falls (MOHCC, 2020). The Zimbabwean government declared a state of the national disaster in response to the COVID-19 pandemic on Friday 27 March, 2020 and this was followed by a nation-wide lockdown on March 30 (Herald News, 2020). COVID-19 studies in Zimbabwe have already been done, for example; Makurumidze *et al*. (2020), Matsungo & Chopera (2020), Mackworth-Young *et al*. (2020) and Dzinamarira *et al*. (2020) but no research has formally presented a forecasting model for the country and yet forecasting COVID-19 case volumes is very important (Medina-Mendieta *et al*., 2020; Li *et al*., 2020; Zhao *et al*., 2020; Liu *et al*., 2020; Lai *et al*., 2020; Khakharia *et al*., 2020) especially with regards to understanding its evolution and consequently helping decision makers to slow down or arrest its spreading (Velasquez & Lara, 2020; Yousaf *et al*., 2020; Ribeiro *et al*., 2020). In fact, modelling and forecasting COVID-19 dynamics is fundamental to being able to act timeously and take the best safety measures for the population (Stochitoiu *et al*., 2020; Petrica *et al*., 2020). Predicting COVID-19 is also critical, especially when it comes to ensuring that healthcare systems are adequately prepared for the ongoing pandemic (Barrett *et al*., 2020). In this study, we attempt to model and forecast daily confirmed COVID-19 cases in Zimbabwe over the period 20March 2020 to 10December, 2020; with an out-of-sample period of 11December, 2020 to 29April 2021.

METHODOLOGY

In this study we apply the ANN model, which has undoubtedly attracted considerable attention in predictive modelling (Gomes *et al*., 2011). The ANN model has the capacity to learn, memorize, create relationships and make predictions (Ozkan & Erbek, 2003; Paswan *et al*., 2018). While there are a number of activation functions, this study uses the hyperbolic tangent function (Gomes *et al*., 2011). This activation function will be used as illustrated in figure 1 below, which is basically shows a generalized ANN architecture.

Figure 1:



Adapted from Fauziah & Gunaryati (2018)

This study is based on newly confirmed daily COVID-19 cases (reffered to as the ZW series in this study) for all age groups in Zimbabwe. The data covers the period 20 March 2020 to 10 December 2020 while the out-of-sample forecast covers the period 11 December 2020 to 30 April 2021. All the data employed in this research paper was gathered from the COVID-19 data repository prepared by the CSSE at JH University.

FINDINGS OF THE STUDY

DESCRIPTIVE STATISTICS

Table 1: Descriptive statistics

Mean	Median	Minimum	Maximum
41.703	17.000	0.00000	490.00
Std. Dev.	C.V.	Skewness	Ex. Kurtosis
64.832	1.5546	3.3327	15.779
5% Perc.	95% Perc.	IQ range	Missing obs.
0.00000	151.20	60.000	0

ANN MODEL SUMMARY FOR COVID-19 DAILY CASES IN ZIMBABWE

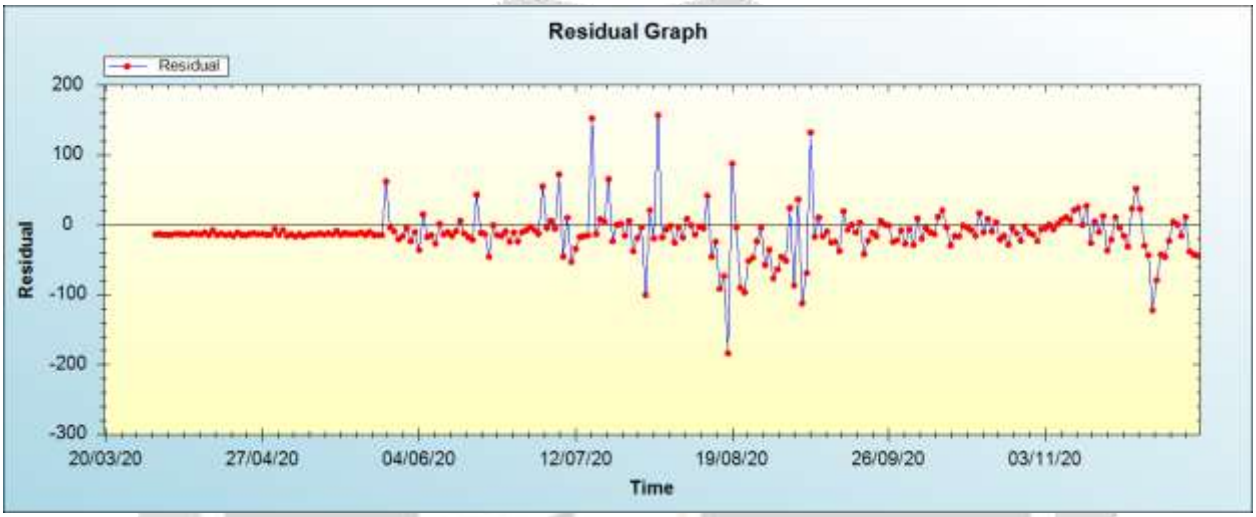
Table 2: ANN model summary

Variable	ZW
Observations	254 (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	0.129020
MSE	1233.565468
MAE	22.751826

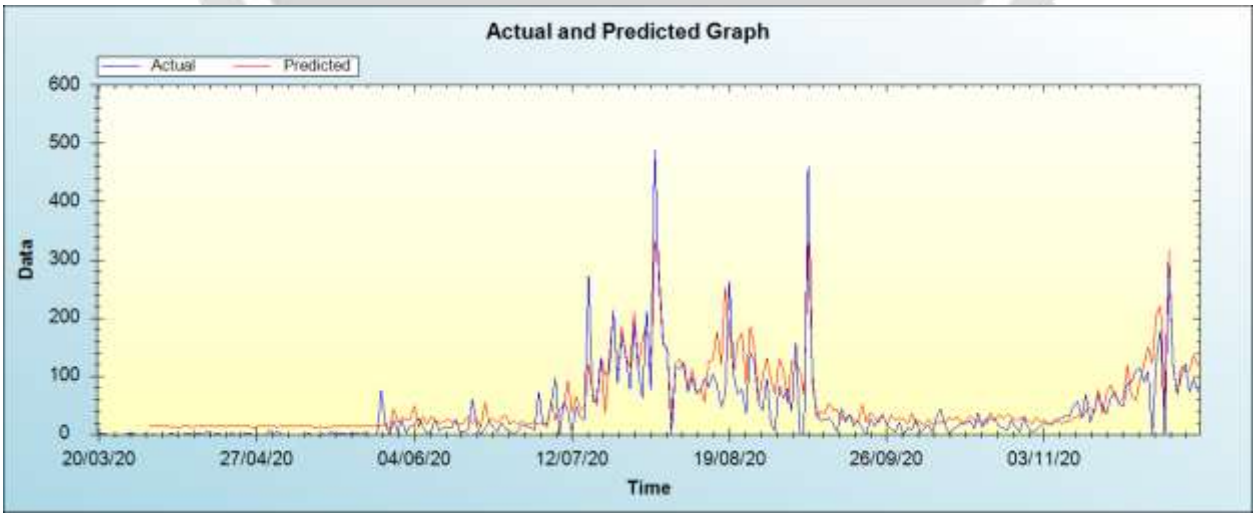
Residual Analysis for the ANN model

Figure 2: Residual analysis



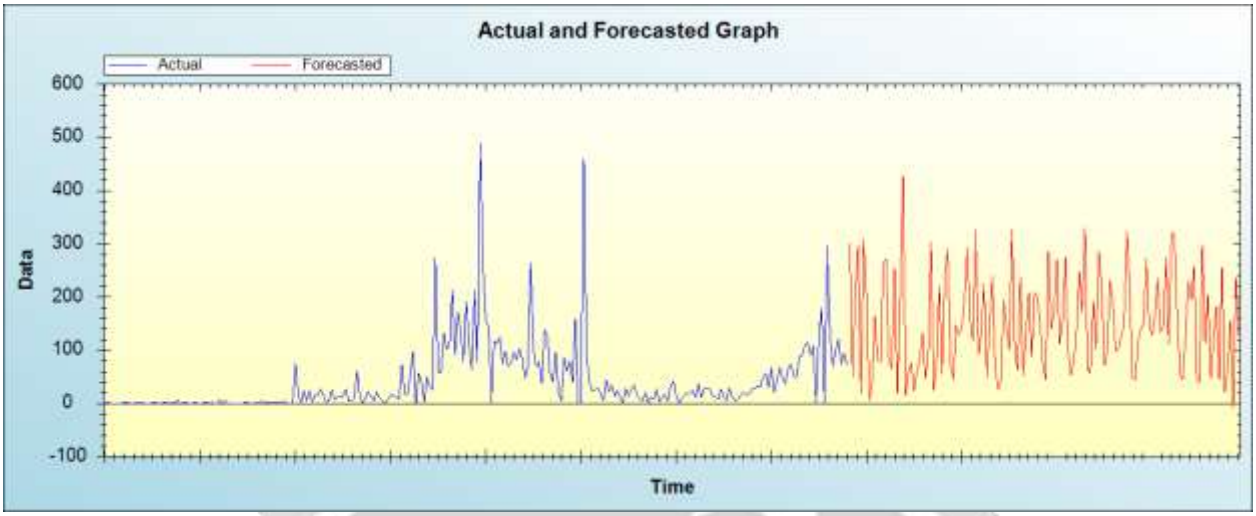
In-sample Forecast for ZW

Figure 3: In-sample forecast for the ZW series



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

Figure 4: Out-of-sample forecast for ZW: actual and forecasted graph



Out-of-Sample Forecast for ZW: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Day/Month/Year	Forecasted daily new COVID-19 cases
11/12/20	301.4258
12/12/20	49.3998
13/12/20	208.2450
14/12/20	297.3225
15/12/20	18.8330
16/12/20	309.1406
17/12/20	203.2471
18/12/20	3.5279
19/12/20	37.7804
20/12/20	165.6038
21/12/20	80.2743
22/12/20	78.0803
23/12/20	264.4901
24/12/20	272.5054

25/12/20	83.8117
26/12/20	64.8108
27/12/20	253.2606
28/12/20	19.9196
29/12/20	193.3894
30/12/20	428.6373
31/12/20	14.8379
01/01/21	60.4241
02/01/21	76.6629
03/01/21	23.7345
04/01/21	59.2416
05/01/21	82.5552
06/01/21	134.1178
07/01/21	46.5433
08/01/21	83.9122
09/01/21	303.6240
10/01/21	23.4718
11/01/21	70.0140
12/01/21	220.9767
13/01/21	56.2579
14/01/21	242.0958
15/01/21	291.0200
16/01/21	73.2769
17/01/21	43.9281
18/01/21	147.4854
19/01/21	128.6116

20/01/21	141.3203
21/01/21	195.8138
22/01/21	294.8299
23/01/21	157.4299
24/01/21	117.3278
25/01/21	325.0111
26/01/21	91.1758
27/01/21	133.4444
28/01/21	224.1528
29/01/21	48.3666
30/01/21	150.8990
31/01/21	239.0780
01/02/21	66.6004
02/02/21	25.6749
03/02/21	41.8399
04/02/21	195.9571
05/02/21	146.6575
06/02/21	101.0910
07/02/21	327.3027
08/02/21	90.9929
09/02/21	63.0791
10/02/21	238.5428
11/02/21	51.9222
12/02/21	136.5056
13/02/21	208.0699
14/02/21	87.8735

15/02/21	209.2490
16/02/21	201.7632
17/02/21	154.5446
18/02/21	73.7860
19/02/21	45.4609
20/02/21	286.4471
21/02/21	140.5113
22/02/21	170.1541
23/02/21	269.6693
24/02/21	112.2727
25/02/21	154.3154
26/02/21	274.4354
27/02/21	99.3309
28/02/21	52.6370
01/03/21	78.1081
02/03/21	133.3156
03/03/21	248.6420
04/03/21	170.3279
05/03/21	329.7226
06/03/21	60.8644
07/03/21	57.9554
08/03/21	193.6516
09/03/21	100.9016
10/03/21	286.4391
11/03/21	220.6955
12/03/21	71.1095

13/03/21	96.2488
14/03/21	233.3161
15/03/21	188.7133
16/03/21	97.1879
17/03/21	101.6824
18/03/21	126.1631
19/03/21	146.3777
20/03/21	324.3656
21/03/21	225.4280
22/03/21	47.6137
23/03/21	44.1587
24/03/21	117.3709
25/03/21	139.8558
26/03/21	152.5558
27/03/21	273.1307
28/03/21	146.9962
29/03/21	127.7608
30/03/21	162.8616
31/03/21	234.9761
01/04/21	133.0264
02/04/21	145.4916
03/04/21	274.0293
04/04/21	110.8364
05/04/21	319.6215
06/04/21	318.5149
07/04/21	161.9352

08/04/21	53.2009
09/04/21	44.5216
10/04/21	130.2695
11/04/21	231.2777
12/04/21	195.0685
13/04/21	257.0934
14/04/21	41.0452
15/04/21	40.0910
16/04/21	298.6231
17/04/21	112.6304
18/04/21	205.3503
19/04/21	46.9428
20/04/21	122.4856
21/04/21	181.5808
22/04/21	44.9367
23/04/21	256.0944
24/04/21	20.9470
25/04/21	67.8998
26/04/21	155.5380
27/04/21	-8.5365
28/04/21	235.9080
29/04/21	126.8867

Figure 5: Graphical Presentation of Predicted ZW

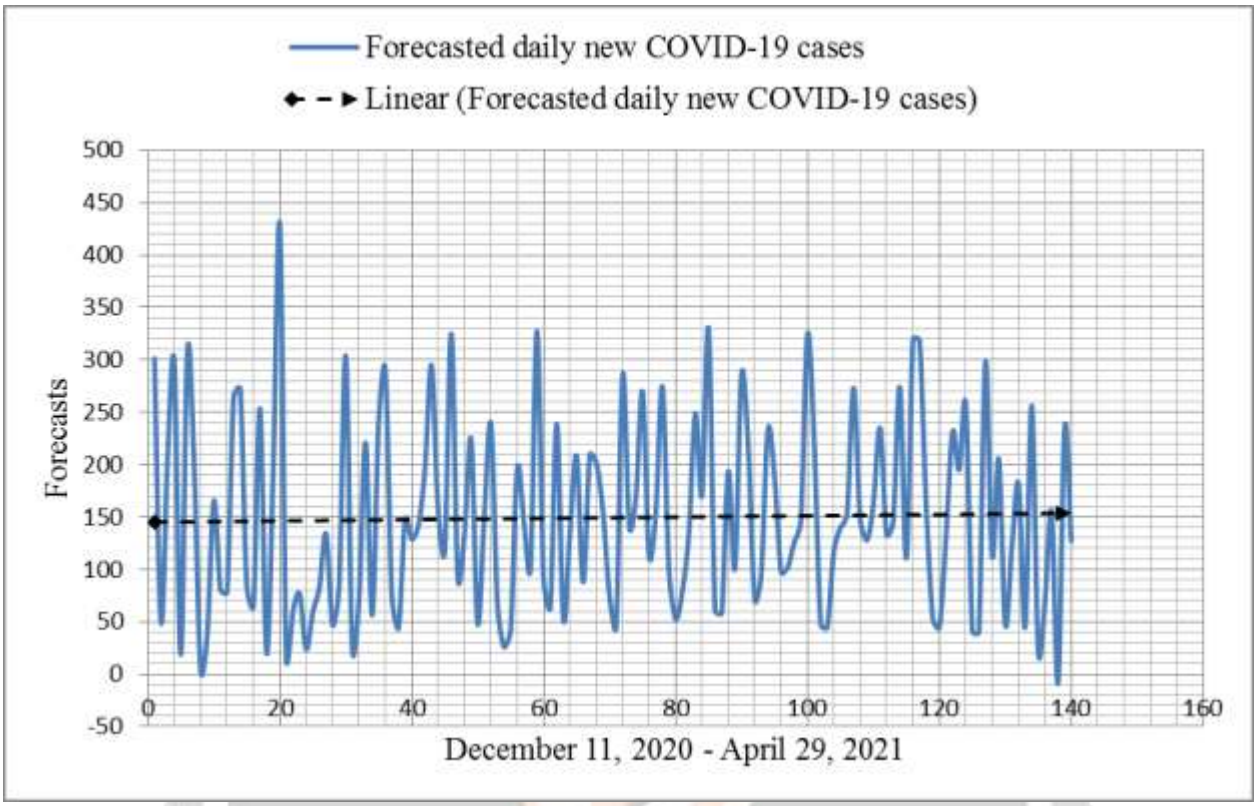


Table 1 shows that over the study period the minimum and maximum number daily new COVID-19 cases were 0 and 490.The average daily new cases were approximately 41 cases per day. The data is positively skewed with a kurtosis value of 15.779 meaning that the data is not normally distributed. The residual graph and forecast evaluation criteria indicate that the applied ANN model is stable and suitable for forecasting daily new COVID-19 cases in Zimbabwe. The out-of sample forecasts indicate that the projected daily new COVID-19 cases will generally range between 0 – 330 cases throughout the out of sample period.

CONCLUSION & RECOMMENDATIONS

COVID-19 has indeed spread all over the world at an astonishing rate, catching many people unaware and this has given birth to new challenges to the research community especially with regards to predicting the future evolution of the pandemic. In this research paper, we applied the artificial neural network approach to analyze daily new COVID-19 cases in Zimbabwe. The employed model is stable and acceptable for predicting COVID-19 cases in the country. The model reveals that the pandemic is not yet over in the country, as 0 – 330 cases per day, are generally expected over the out-of-sample period. We strongly encourage the government of Zimbabwe to continue enforcing control and preventive measures such as mass-media sensitization, social distancing, face-mask wearing, contact tracing, disinfection and decontamination of infected areas, washing and sanitization of hands and so on as advised by the WHO. These measures are expected to go a long way in arresting a further increase or second wave of infections in Zimbabwe.

REFERENCES

[1] Alazab, M., *et al*. (2020). COVID-19 Prediction and Detection Using Deep Learning, *International Journal of Computer Information Systems and Industrial Management Applications*, 12: 168 – 181.

[2] Barret, K., *et al*. (2020). Estimation of COVID-19-induced Depletion of Hospital Resources in Ontario, Canada, *CMAJ*, pp: 1 – 7.

[3] Chakraborty, I., & Maity, P. (2020). COVID-19 Outbreak: Mitigation, Effects on Society, Global Environment and Prevention, *Science of the Total Environment*, 728: 1 – 18.

[4] Chan, J. F. W., *et al*. (2020). A Familial Cluster of Pneumonia Associated With the 2019 Novel Coronavirus Indicating Person-to-Person Transmission, *The Lancet*, 395: 514 – 523.

[5] Chowell, G., *et al*. (2020). Real-time Forecasts of the COVID-19 Epidemic in China From February 5th to February 24th, 2020, *Infectious Diseases Modelling*, 5: 256 – 263.

[6] Dzinamarira, T., *et al*. (2020). Coronavirus Disease 2019 (COVID-19) Response in Zimbabwe: A Call for Urgent Scale up of Testing to Meet National Capacity, *Clinical Infectious Diseases*, pp: 1 – 8.

[7] Fong, S. J., *et al*. (2020). Finding an Accurate Early Forecasting Model From a Small Dataset: A Case of 2019-nCoV Novel Coronavirus Outbreak, *International Journal of Medicine and Artificial Intelligence*, 6 (1): 132 – 137.

[8] Guan, W. J., *et al*. (2020). Clinical Characteristics of Coronavirus Diseases 2019 in China, *New England Journal of Medicine*, 382 (18): 1708 – 1720.

[9] COVID-19 Repository By the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University.

[10] Dong, E., et al. (2020). An Interactive Web-based Dashboard to Track COVID-19 in Real Time, *Lancet Infectious Diseases*, 20 (5): 533 – 534.

[11] Herald News (2020). 21 Days Lockdown, *Herald News*, Harare

[12] Khakharia, A., *et al*. (2020). Outbreak Prediction for COVID-19 for Dense and Populated Countries Using Machine Learning, *Annals of Data Science*, pp: 1 – 19.

[13] Lai, A., *et al*. (2020). Early Phylogenetic Estimate of the Effective Reproduction Number of SARS-CoV-2, *Journal of Medical Virology*, pp: 1 – 10.

[14] Lai, A., *et al*. (2020). Early Phylogenetic Estimate of the Effective Reproduction Number of SARS-CoV-2, *Journal of Medical Virology*, pp: 1 – 10.

[15] Li, Q., *et al*. (2020). Early Transmission Dynamics in Wuhan, China, of Novel Coronavirus-infected Pneumonia, *New England Journal of Medicine*, 382: 1199 – 1207.

[16] Liu, Y. C., *et al*. (2020). A Locally Transmitted Case of SARS-CoV-2 Infection in Taiwan, *New England Journal of Medicine*, 382: 1070 – 1072.

[17] Mackworth-Young, C. R. S., *et al*. (2020). Here We Cannot Practice What is Preached: Early Qualitative Learning From Community Perspectives on Zimbabwe's Response to COVID-19, *Bulletin of the World Health Organization*, pp: 1 – 19.

[18] Makurumidze, R. (2020). Coronavirus-19 Disease (COVID-19): A Case Series of Early Suspected Cases Reported and the Implications Towards the Response to the Pandemic in Zimbabwe, *Journal of Microbiology, Immunology and Infection*, 53: 493 – 498.

[19] Matsungo, T. M., & Chopera, P. (2020). The Effect of the COVID-19 Induced Lockdown on Nutrition, Health and Lifestyle Patterns Among Adults in Zimbabwe, *medRxiv*, pp: 1 – 21.

[20] MOHCC (2020). COVID-19 Situation Report, *MOHCC*, Harare.

[21] Petrica, M., *et al*. (2020). A Regime Switching Model on COVID-19 Analysis and Prediction in Romania, *medRxiv*, pp: 1 – 6.

[22] Ribeiro, M. H. D. M., *et al*. (2020). Short-term Forecasting of COVID-19 Cumulative Confirmed Cases: Perspectives for Brazil, *Chaos, Solitons and Fractals*, 138 (2020): 1 – 13.

[23] Singhal, A., *et al*. (2020). Modeling and Prediction of COVID-19 Pandemic Using Gaussian Mixture Model, *Chaos, Solitons and Fractals*, 138 (2020): 1 – 8.

[24] Stochitoiu, R. D., *et al*. (2020). A Self-Supervised Neural-Analytic Method to Predict the Evaluation of COVID-19 in Romania, *medRxiv*, pp: 1 – 20.

[25] Uddin, M. I., Shah, S. A. A., & Al-Khasawneh, M. A. (2020). A Novel Deep Convolutional Neural Network Model to Monitor People Following Guidelines to Avoid COVID-19, *Journal of Sensors*, pp: 1 – 15.

[26] Velasquez, R. M. A., & Lara, J. V. M. (2020). Forecast and Evaluation of COVID-19 Spreading in USA With Reduced-space Gaussian Process Regression, *Chaos, Solitons and Fractals*, 138 (2020): 1 – 9.

[27] WHO (2020). Coronavirus, *WHO*, Geneva.

[28] Yousaf, M., *et al*. (2020). Statistical Analysis of Forecasting COVID-19 for Upcoming Month in Pakistan, *Chaos, Solitons and Fractals*, 138 (2020): 1 – 15.

[29] Zhao, S., *et al*. (2020). Preliminary Estimation of the Basic Reproduction Number of Novel Coronavirus (2019-nCoV), in China From 2019 to 2020: A Data Driven Analysis in the Early Phase of the Outbreak, *International Journal of Infectious Diseases*, 92: 214 – 217.

[30] Gomes, G. S. S., *et al*. (2011). Comparison of New Activation Functions in Neural Network for Forecasting Financial Time Series, *Neural Computing & Applications*, 20: 417 – 439.

[31] Ozkan, C., & Erbek, F. S. (2003). The Comparison of Activation Functions for Multispectral Landsat TM Image Classification, *Photogrammetric Engineering & Remote Sensing*, 69 (11): 1225 – 1234.

[32] Paswan, R. P., *et al*. (2018). Comparison of Abilities of Different Activation Functions of Artificial Neural Networks to Predict Crop Area and Crop Production, *International Journal of Pure and Applied Bioscience*, 6 (6): 212 – 220.

[33] Fauziah, F. N., & Gunaryati, A. (2018). Comparison Forecasting With Double Exponential Smoothing and Artificial Neural Network to Predict Price of Sugar, *IJSSST*, 13 (1): 1 – 8.