*Asian Journal of Research in Computer Science*

*7(3): 55-62, 2021; Article no.AJRCOS.64807*
*ISSN: 2581-8260*

# Deep Learning Detection of COVID-19, Temporal Variation and its Link with Temperature in Nigeria

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***Author's contributions***

*The sole author designed, analysed, interpreted and prepared the manuscript.*

***Article Information***

DOI: 10.9734/AJRCOS/2021/v7i330182
Editor(s):
(1) Dr. R. Gayathri , Anna University, India,
(2) Dr. Hasibun Naher , BRAC University, Bangladesh.
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Reviewers:
(1) Mauricio Mhirdaui Peres , Federal University Of Rio Grande Do Norte,Brazil.
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(3) Muhammed Mizher Radhi , Middle Technical University (MTU), Iraq.
Complete Peer review History: http://www.sdiarticle4.com/review-history/64807

***Original Research Article***

***Received 02 January 2021***
***Accepted 16 February 2021***
***Published 29 March 2021***

## ABSTRACT

COVID-19 was announced as a global pandemic on 11 March 2020 by the World Health Organization due to its spread globally. Nigeria recorded its first case on 27 February 2020. Since then, it has spread to all parts of the country. In this paper we study the effectiveness and skill performance of deep learning architectures in assisting health workers in detecting COVID-19 infected patient through X-ray images. Analytical deductions obtained from 500 X-ray images of both infected and non-infected patients confirmed that our proposed model InceptionV3 is effective in detecting COVID-19 and attain an average accuracy of 92%. The relationship or link between the COVID-19 daily occurrence and two meteorological variables (minimum and maximum temperatures) are further assessed. The result also indicated that the cases recorded in Wednesdays and Fridays are observed to be higher than other days which usually coincide with either religious activities or market days in the country, while a progressively decline in weekday cases is observed towards the weekend with Sundays (ranging from 152 to 280 cases) having the lowest cases. The study further indicated statistically that COVID-19 daily cases significantly decline when maximum and minimum temperature are increasing (-0.79 and -0.44 correlation coefficient).

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*Keywords: Deep learning; artificial intelligence; COVID-19; X-ray images; VGG19 and Inceptionv3.*

## 1. INTRODUCTION

COVID-19 which means Coronavirus disease 2019 is an Infectious disease caused by Severe Acute Respiratory Syndrome Corona virus 2 [1,2]

The first occurrence of COVID-19 infection cases was reported in Wuhan (capital of Hubei province), China on 31 December 2019 by health authorities while the first case outside China was announced on 13 January 2020 [3]. The World Health Organization has reported that the number of people infected outside of China has exceeded the number of new cases of infection reported in China for the first time in February 2020 [4] and by 13 March 2020, more than 40 countries and territories had reported deaths on every continent as a result. Nigeria, a West African country recorded its first non-local citizen case of COVID-19 on February 27, 2020 [5] and its first indigenous case on March 30, 2020. As of August 22, 2020, reported Nigerian cases were reported on COVID– 19 had risen to 51,905 with 997 deaths (Fig. 1), 38,767 dismissed and 12,141 currently receiving treatment [5]. Lagos State (Nigeria) has recorded an increasing soaring number of infected persons than any other state in the country.

COVID-19 has now become a global pandemic due to its surging global spread. It is a difficult task to detect who have been exposed because they do not show symptoms immediately. Therefore, it became imperative to research on methods to estimate the number of people who may be infected on daily basis to take proper action. Artificial Intelligence can be used as an assisting diagnosis tool to detect a person with COVID-19. Nevertheless there are few literatures on COVID-19, this study is centered on the use of deep learning applications in diagnosing COVID-19 infected patients and COVID-19 variability with temperature in Nigeria.

Narin et al. [6] proposed and developed a Convolutional Neural Network (CNN) based diagnosis model to detect infectious COVID-19 patients applying 100 chest X-ray images, 50 of which are COVID-19 patients and the other 50 for healthy people. They reviewed the skill of three (3) Convolutional Neural Network (CNN) models; ResNet-50, Inception-v3, and Inception-ResNet-v2 using five-fold verification and reported that ResNet-50 had the best skill performance and accuracy of 98%.

In submission to Narin et al. [6], Hemdan et al. [7] developed a deep learning based architecture, called COVIDX-Net that could assist radiologists in diagnosing infectious COVID-19 patients using chest X-ray. They validated their developed deep learning based system using a database of 50 X-ray images divided into two categories: 25 COVID-19-positive images and 25 negative images of COVID19. The images used were 224 × 224 pixels in size. The proposed COVIDX-Net system deployed seven (7) deep learning models: MobileNet, ResNet-v2, Inception ResNet-v2, Xception, Inception-v3, Dense Net, and VGG19 converted. The authors test results indicated that the VGG19 and Dense Net models produced similar F-score to 91% of COVID-19 cases. Wang et al. [8] developed a deep learning COVID-Net architecture for detecting infectious COVID-19 patients using CXR images which proved to be reliable tool for health workers.

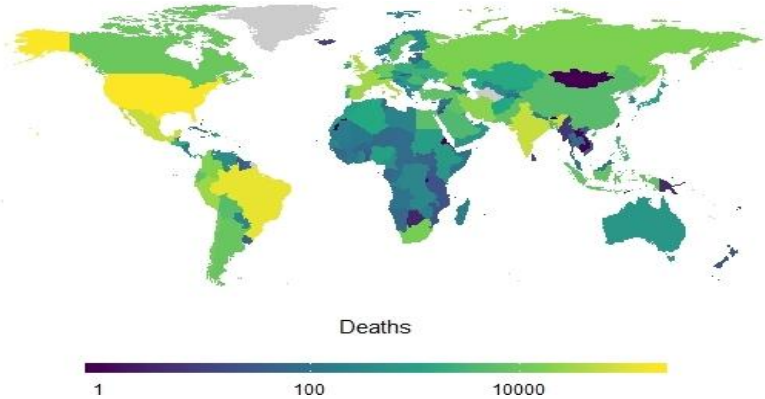


**Fig. 1. Geospatial Plot of COVID-19 Deaths cases as of August 22, 2020**

Deep learning models like VGGNet, GoogleNet, InceptionV3 and ResNet trained in ImageNet datasets learn to identify images and complex formats can be learned by later layer layers over these features, making them suitable for COVID-19 detection.

This paper contributes to advancement of recent studies on COVID-19 detection and its dynamism in relation to temperature (minimum and maximum temperatures). Thus, a preliminary baseline is given to demonstrate the potential of deep learning as a diagnosis tool in assisting health workers for future research whilst the relationship between COVID–19 daily cases and some meteorological temperature variables are examined.

## 2. MATERIALS AND METHODS

### 2.1 Data Source

Daily COVID-19 active, confirmed, recovered and death cases across Nigeria for 177 days period (February 28 to August 22 2020) are retrieved from the website of Nigerian Centre for Disease Control (https://ncdc.gov.ng/). Shiny R [9] daily live Corona virus dashboard was built to track real-time daily active, confirmed, recovered and death cases across Nigeria which presented in Fig. 2.

Deep learning (Keras transfer learning application) would be use in diagnosing of infections patient with COVID-19 using Chest X-ray images. The experimentation was carried on Google Colab Notebook with Tesla GPU using two (2) transfer learning architectures from Keras API which includes VGG19 and InceptionV3. The Chest X-ray dataset was obtained from the Kaggle database [10] with a combined sample of 500 images of both COVID-19 and healthy patients. To ascertain the skill performance of the proposed deep learning based COVID-19 diagnosis tool, the following standard metrics: accuracy, precision, recall, and F-measure was adopted [11]. This metrics would be evaluated using the Scikit-Learn 0.24.0 python library [12].

In investigating the link between COVID–19 daily cases with temperature in the Nigeria, we used Lagos as a reference station, since it became the epidemic center of the country, owing to high cases seen daily. Daily maximum temperature (°C), and minimum temperature (°C) are retrieved from the archives of ERA-Interim Reanalysis.

### 2.2 Model Design

The Model design of our deep learning COVID-19 detection algorithm comprises of several steps as proposed by Alazab et-al [11] below;

1. Retrieve chest X-ray images for COVID-19 patients and healthy persons.
2. Define the images in a feature space and apply deep learning.
3. Divide the dataset into two sets: Training set (80%) and a testing set (20%).
4. Evaluate the skill performance of the deep learning-based diagnosis model on the testing dataset.

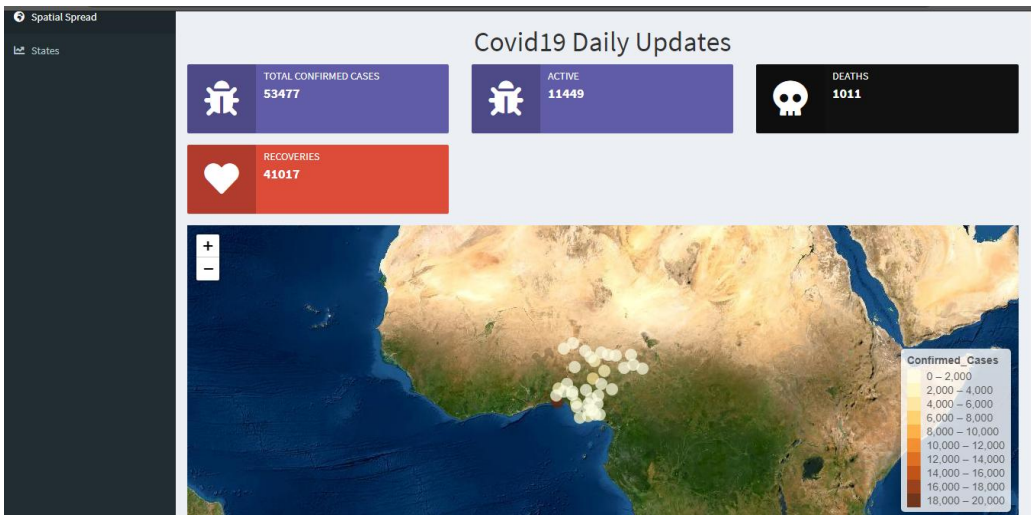


**Fig. 2. Daily Online Geospatial Nigeria Coronavirus Tracker (built with R programming) (https://precious-ebiendele.shinyapps.io/covid9JA/)**

## 3. EXPERIMENTAL RESULTS AND DISCUSSIONS

In this session, the results of the COVID–19 time series variation of weekdays, confirmed, active, death cases, deep learning detection and relationship with temperature is presented.

### 3.1 Time Series Variation of COVID–19 Daily Cases

Time series variation of COVID-19 cases between February 27 and August 22 is presented in Fig. 3, this period has recorded cumulative case of 51,905. Average weekly (February 27 to August 22) deduction shows that Saturday has the highest occurrence rate of between 153 and 348 (Table 1). Sunday's has the lowest occurrences between 152 to 280 (Table 1) confirmed cases, while the largest increase in confirmed cases is usually observed from Tuesday to Wednesday, this temporal trend are in agreement with studies from Adeyeri et al. [13]. Also as observed, active cases in Nigeria have seen a decline since august as a result of sharp increase in recoveries cases across the country as seen in (Fig. 4 to 5).

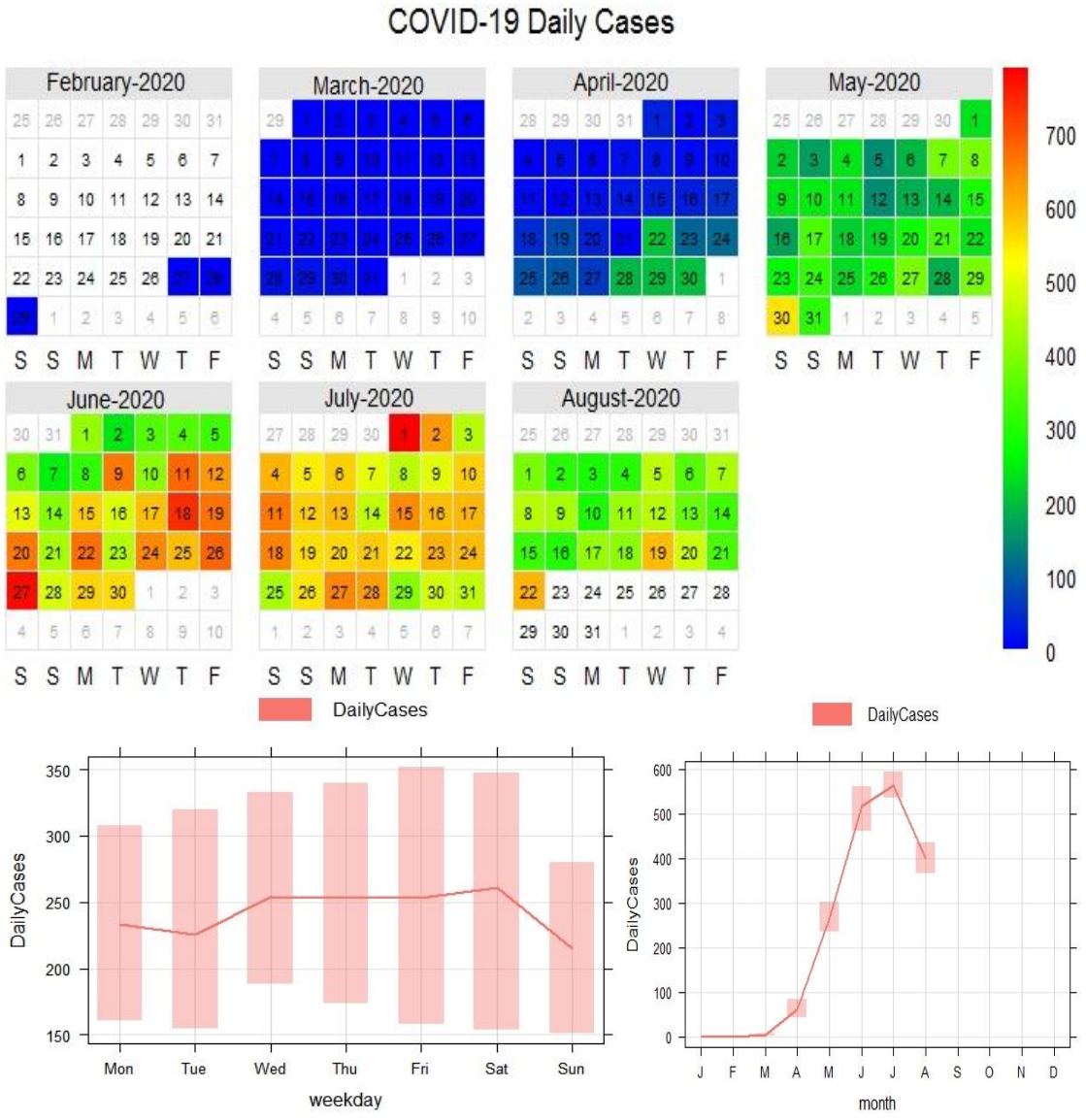


**Fig. 3. Temporary distribution of daily new cases**

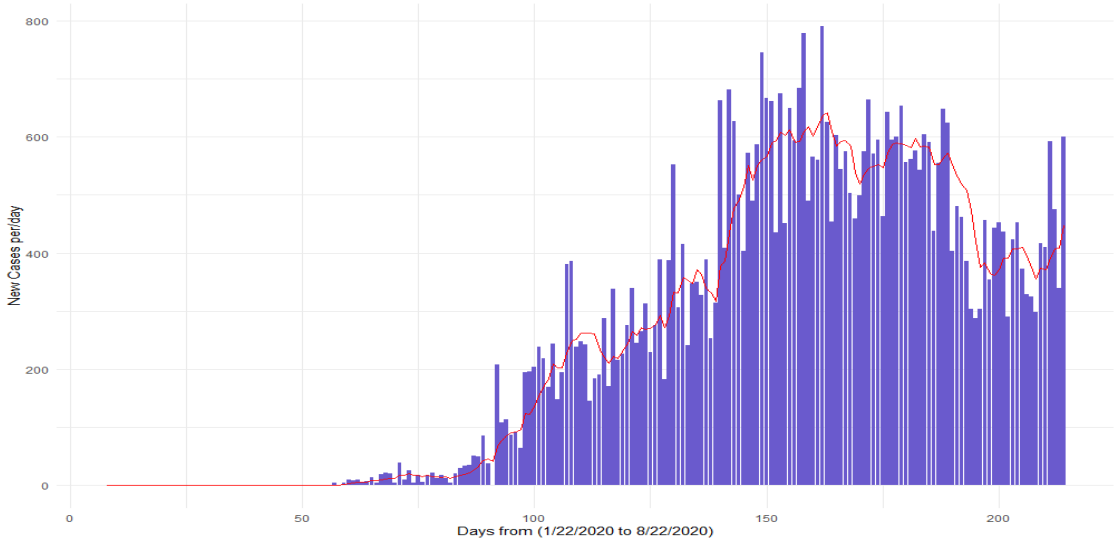


**Fig. 4. Daily New Cases of Coronavirus with 7 days Averages**

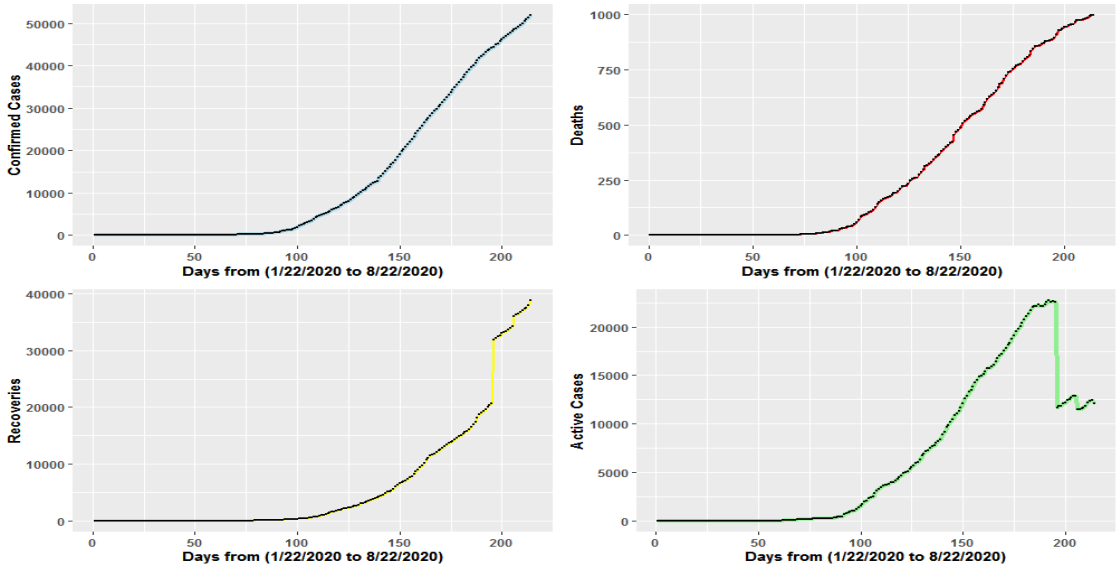


**Fig. 5. Covid-19 cumulative time series plot of confirmed, deaths, recoveries and active cases**

**Table 1. Covid-19 weekdays daily statistics**

| Weekdays | Monday | Tuesday | Wednesday | Thursday | Friday | Saturday | Sunday |
|---|---|---|---|---|---|---|---|
| Lower | 161 | 155 | 188 | 173 | 158 | 153 | 152 |
| Upper | 307 | 320 | 333 | 339 | 352 | 348 | 280 |
| Mean | 234 | 225 | 255 | 253 | 254 | 261 | 215 |

### 3.2 Training of VGG19 and InceptionV3 Model for COVID-19 Detection

This study developed a deep learning diagnosis model to assist health workers in detecting COVID-19. The model is validated using a designated test chest X-ray Image datasets. All chest X-ray images used were resized to 224 × 224 pixels while ignoring the aspect ratio. Fig. 6 shows the chest X-ray images of healthy patients

and patients with COVID-19, respectively. The collected data was randomly divided into a set of training data and test data.

The COVID-19 detector for both VGG19 and InceptionV3 was trained and tested on extracted chest X-ray image datasets, 80% was designated for training and the remaining 20% was used for testing. Fig. 7 shows the testing accuracy and loss of VGG19 and InceptionV3 during training and testing at 100 epochs. InceptionV3 had a better performance than VGG19 with average accuracy of 92%.

Deductions from our confusion matrix as depicts in Fig. 8 indicated that both models show similar performance accuracy of 95% in diagnosis of infectious COVID-19 patients, while inceptionv3 outperform VGG19 with an accuracy of 89% in detecting healthy chest x-ray images as seen in Table 2.

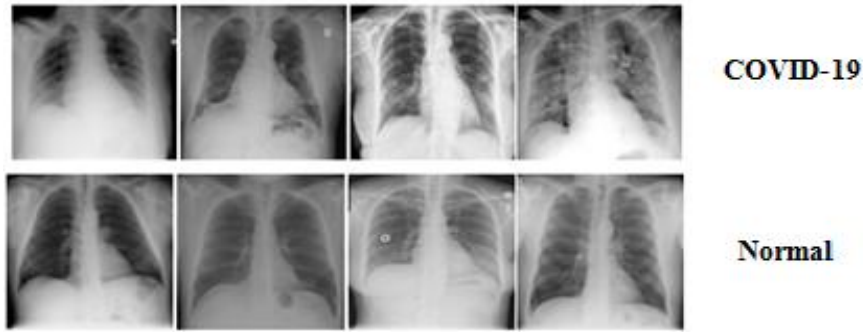


**Fig. 6. Chest X-ray image sample of COVID-19 and normal**

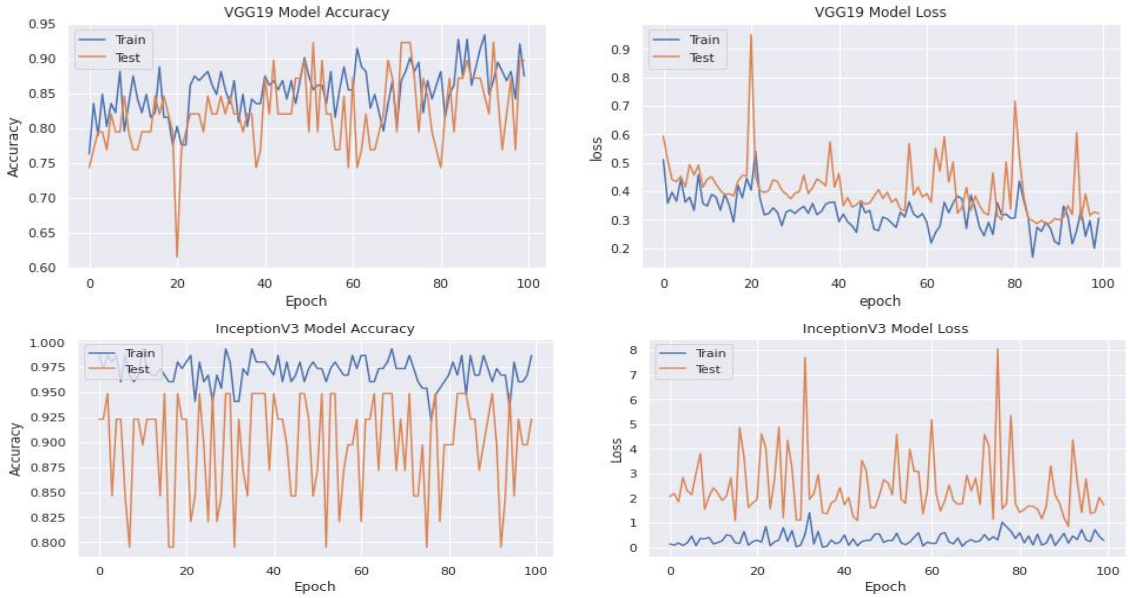


**Fig. 7. Model accuracy and loss of VGG19 and inceptionv3 on train and test chest X-ray images**

**Table 2. Deep learning model accuracy performance**

| Deep learning model | Overall accuracy (%) | Detection Accuracy of COVID-19 Chest X-ray (labeled as 1) | Detection Accuracy of healthy Chest X-ray Image (labeled as 0) |
|---|---|---|---|
| VGG19 | 90% | 95% | 84% |
| InceptionV3 | 92% | 95% | 89% |

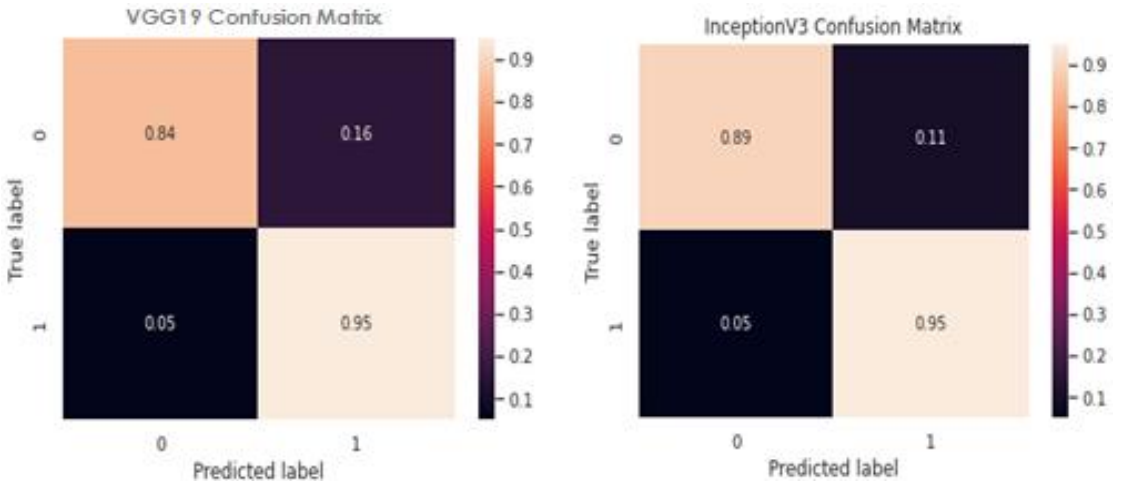


**Fig. 8. Confusion matrix performance of VGG19 and InceptionV3 on test chest X-ray images**

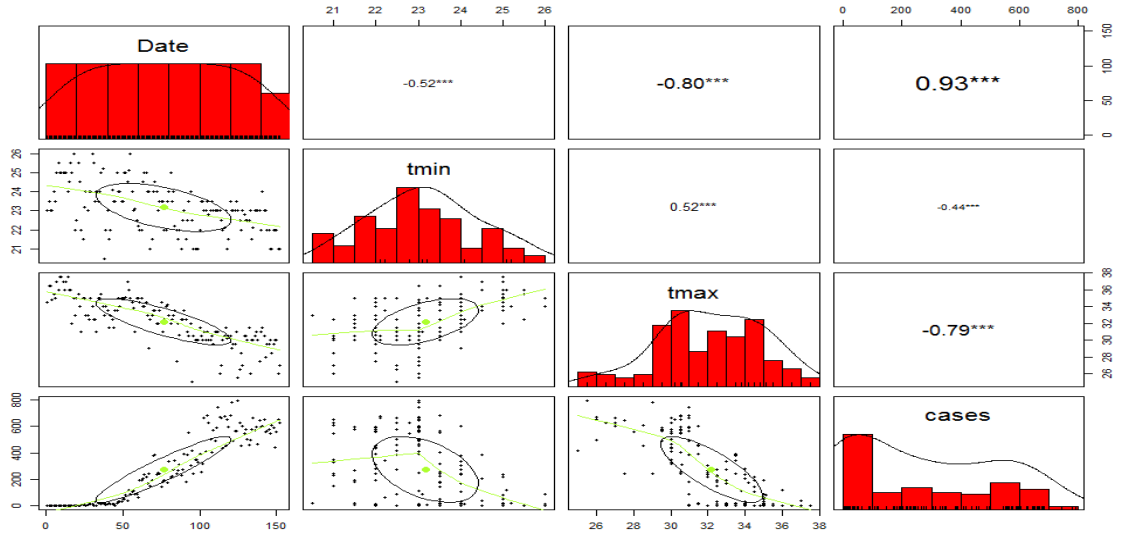


**Fig. 9. Correlation plot between daily meteorological parameters and COVID-19 incidence between February and July with a 7-day lag in COVID confirmed cases in Nigeria**

### 3.3 Statistical Relationship between Temperature and COVID–19

Deduction from Pearson's statistical correlation test between COVID-19 daily cases and temperature variables (–0.79 and -0.44 at $P \leq 0.01$) in Lagos (Fig. 9) explains the link between maximum temperature, minimum temperature and COVID–19. The correlation result indicated that Covid-19 daily occurrence is seen to decline when maximum and minimum temperature increases. Consequently, the result indicated that maximum and minimum temperatures have a significant relationship with COVID–19 daily cases.

## 4. CONCLUSION

In this study, we explore the potential of VGG19 and InceptionV3 as a diagnosis model to detect infectious COVID-19 patients using chest X-ray images. The proposed deep learning models would assist health workers in rapid and reliable diagnosis of infectious COVID-19 patients. Our results indicated that InceptionV3 was more reliable and achieve an average accuracy of 92%. Also, our study indicated a decrease in active cases seen in late July till August as recoveries rate have seen a surge in country, while cumulative confirmed cases and cumulative death still have a continuous

increase. Our study further ascertain the impact of temperature on COVID-19 daily cases, demonstrating statistically that COVID-19 daily cases significantly decline when maximum and minimum temperature are increasing (-0.79 and -0.44 correlation coefficient) and vice-versa.

Therefore, the deployment of chest X-ray images is recommended for assisting in diagnosing of infectious COVID-19 patients because chest X-rays can be easily obtained at health centers fairly quickly and at affordable costs.

## COMPETING INTERESTS

Author has declared that no competing interests exist.

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