# Three Waves of COVID-19 in India-An Autoregression Model

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## Abstract

COVID-19, the infectious disease caused by the most recently discovered coronavirus is related to the upper respiratory tract family of disorders. It triggers asthma, severe respiratory diseases, cause lung infection and bronchiolitis infections. Though the severity of these infections are getting obsolete but may remain in the mild forms of waves in our lives. A thorough study about its spread across the globe, its prediction and understanding the transmission patterns, through various statistical models might be one of the effective ways to provide an insight to various aspects of the disease and suggest prevention strategies. In the light of this, Auto Regression (AR) models are developed for the confirmed cases with 5 days lag, in 6 different states of India. The data has been trained from July 2020 to July 2023 taking into account the three most impactful corona waves. August 2022 data has been used for testing & validating the models. Based on the population size and total number of confirmed cases the Indian states have been classified into three categories: Most affected, moderately affected & least affected states. Two states have been selected in each of these categories for the purpose of research study here. Auto Regression models are developed for the purpose of prediction in each of the states for all the 3 waves. Finally, the prediction of fourth wave is done for the month of July 2022 by using the third wave AR models. The results varies from state to state for each AR model.

## Keywords
COVID-19, Data Analysis, Auto Regression Model, Prediction

## 1. Introduction
A new contagious disease was first discovered in Wuhan, China at the end of 2019 known as corona virus infectious disease or Covid 19. In India, the first confirmed case was identified in the state of Kerala on 30th January 2020. The common symptoms observed in the disease are fever, cold, throat pain, tiredness and difficult breathing. It triggers asthma, severe respiratory diseases, cause lung infection and bronchiolitis infections. The governments and medical practitioners across the globe tried to control the pandemic situation by imposing quarantine restrictions like social distancing, wearing mask and travelling restrictions etc, but still the virus took the shape of a pandemic and was spread in the whole world in the form of different waves that caused a huge loss of human lives. Though the severity of these infections are getting obsolete with time but its impact may remain in the mild forms of waves in our lives.

The researchers across the world are trying their level best to address the situation in their own best possible ways so that the future doesn't see this kind of pandemic anymore. Mathematical Modelling could also be proved as one of the most effective tools for studying the corona virus dynamics. Many researchers are trying to develop the predictive models and forecast the future using them. The literature shows that an auto regression model is one of the frequently used methods that gives the better results to predict the number of cases. In this study, we propose an AR model for confirmed cases in least, moderately and most affected states of India by dividing the data into three waves based on the trend. The output of the model is used to predict the number of cases in fourth wave.

### 1.1 Objectives

- To identify the most affected, moderately affected & least affected states of India
- To develop the predictive Auto Regression models for two states under each category
- To predict the confirmed cases for fourth COVID wave

## 2. Literature Review

Sarkar et al (2020) proposed a mathematical model consisting of six compartments they are isolated infected , infected, susceptible, asymptomatic, recovered, and quarantined susceptible. A sensitivity analysis between the model predictions to parameters estimation, demonstrated that a reduction in the contact rate between infected & uninfected individual and restriction on social distancing can suppress the spread of the infection.

Rajgopal et al (2020) considered both classical and fractional order models and estimated the parameters by using the data of Italy. The results proves that fractional order model has less RMSE than classical one and provides a closer forecast to the data.

Maher et al (2020) proposed a dynamic hybrid model that was mainly differentiated into two, modified SERID dynamic model and ARIMA model. The parameters of SEIRD model were fit against observed value of infected, recovered and decreased population, divided by ascertainment rate. Residuals of SEIRD model corrected using ARIMA model. Overall, the results of models provides long & short term forecasts with good confidence.

Zheng et al (2020) proposed a hybrid AI model for predicting COVID-19 in China. They proposed an integration of an improved susceptible infected (ISI) model in which the natural language processing module and LSTM network are embedded. This hybrid model estimates the infection rate for prediction and significantly reduces the errors.

Samui et al (2020) formulated a compartmental mathematical model to analyse, predict and reduce the transmission dynamics of COVID-19 in India and further to study the model simulation, basic reproduction number is evaluated. Later they conducted a sensitivity analysis model to find the relative importance of model parameters to disease transmission.

Bagalia et al (2020) created a global sensitivity analysis to observe the impact of basic reproduction number on a newly developed compartmental epidemic model. This model used intervention strategies like lockdown, quarantine and hospitalization for cumulative and new daily cases in India.

Kumar et al (2020) extended the use of sensitivity analysis to identify the influential model parameters, by estimating the basic reproduction from real time data. They tried to do the prediction on future trends of virus transmission under some control measures.

Swaraj et al (2021) developed a hybrid model using ARIMA model and NAR neural network for daily observed cases in India and based on the performance evaluation parameters models are compared. It notifies that the Hybrid model captures both linearity and non-linearity effectively and reduces the errors significantly.

Luo et al (2021) established prediction models for daily new cases of USA by applying long short – term memory, extreme gradient boosting algorithms. The performance of the model is assessed by evaluating the parameters MAE, MSE, RMSE, MAPE. They conducted sensitivity analysis to find the robustness of predictive model to parameter features by using XGBoost model. The results revealed that alog with predictive assumptions, enforcement of precautionary measures for infected people can eliminate the disease.

Ayoobi et al (2021) examined six deep learning methods and carries out a exhaustive evaluation of three methods namely LSTM, Convolutional LSTM and GRU & their bidirectional extensions on the new cases and new death rate for COVID-19 in Australia and Iran countries. It is shown that bidirectional models have low errors compared to other models.

Bedi et al ( 2021) created a modified SEIRD model for predicting the trend and peak of cases identified in India and four most affected states and then introduced a deep learning LSTM model for trend prediction. LSTM Model are compared with modified SEIRD model for predicting the next 30 days cases.

Saqib et al ( 2021) [12] proposed a hybrid model to predict the number of confirmed cases to overcome the disadvantage of the logistic model's inability and drawbacks of SEIR model. Forecasting the epidemic, peak time & simulation of public health interventions makes the model superior for prediction.

Wang et al (2021) estimated the mortality and prevalence of COVID-19 in south Africa and Nigeria using a hybrid model based on ensemble empirical mode decomposition, autoregressive integrated moving average and nonlinear autoregressive artificial neural network.

Kumari et al (2022) proposed a SEIAQRDT model that can be incorporated to analyse the transmission of corona virus in India. This model incorporates the parameters like asymptotic individuals, patients under quarantine, and transmissions via environment. The existence and stability analysis of disease-free equilibrium and endemic equilibrium points are established.

## 3. Methods

Many researchers have proposed different regression models for the effective prediction. Some authors have proposed ANN for classification and prediction. Based on the total population and the total no of confirmed COVID cases in each state of India, we have classified all the states of India into three categories: Least affected states, moderately affected states and most affected states. Out of 28 states in India, 14 states are most affected, 8 states are moderately affected and 6 states are least affected by the virus. For the purpose of elaborate study two states from each category are chosen and looking at the pattern of the data collected for confirmed COVID cases, during the three different waves, we have developed Auto regression models with five days lag for each wave of the identified states. The chosen states in the category of least affected are Arunachal Pradesh & Meghalaya, in moderately affected states are Punjab & Jammu-Kashmir, whereas the Most affected states are Gujarat & Uttar Pradesh. Further we are trying to develop the ANN models to address the non-linearity of the data pattern. We are also in the process to see if a hybrid model can be developed which comprises of Regression model whenever there is linearity in the data and ANN models for non-linearity within data.

## 4. Data Collection

As mentioned in the previous section, in each category two states are considered, each state data is divided into three different waves based on the increasing and decreasing number of confirmed cases and trend in the data set. From 1st July 2020 to 31st December 2020 data considered as first wave (184 days), 1st January 2021 to 31st December 2021 data as second wave (365 days) and 1st January 2022 to 31st July 2022 data as third wave (212 days). The relevant data has been collected and the following table shows the statistical parameters (Mean & Standard deviation) obtained for the selected states during each wave. Further August 2022 data is considered for forecasting (Table 1).

Table 1. The basic statistics of COVID 19 data for Uttar Pradesh, Gujarat, Jammu Kashmir, Punjab, Meghalaya and Arunachal Pradesh.

| | States | Statistics | First Wave | Second Wave | Third Wave |
|---|---|---|---|---|---|
| Most Affected | Uttar Pradesh | Mean | 3051.48 | 3086.68 | 1844.42 |
| | | Standard Deviation | 1707.43 | 8137.19 | 4057.68 |
| | Gujarat | Mean | 1154.32 | 1606.93 | 1997.35 |
| | | Standard Deviation | 211.88 | 3488.18 | 4498.08 |
| Moderately affected | Jammu and Kashmir | Mean | 616.70 | 60.361 | 582.43 |
| | | Standard Deviation | 337.77 | 1101.57 | 1384.74 |
| | Punjab | Mean | 874.75 | 1200.78 | 798.04 |

| | | | | | |
|---|---|---|---|---|---|
| | | Standard Deviation | 639.19 | 2127.22 | 1796.76 |
| Least affected | Meghalaya | Mean | 72.58 | 195.66 | 50.06 |
| | | Standard Deviation | 56.05 | 236.17 | 90.23 |
| | Arunachal Pradesh | Mean | 89.82 | 105.81 | 49.43 |
| | | Standard Deviation | 76.93 | 146.32 | 109.54 |

## 5. Results and Discussion

### 5.1 Numerical Results

The Auto Regression Model developed with 5 days lag is:

$(1 - \emptyset_1 L - \emptyset_2 L^2 - \emptyset_3 L^3 - \emptyset_4 L^4 - \emptyset_5 L^5) y_t = \text{Constant}$……………..(1)

Where $L^i$ represents lags and $\emptyset_i$ represents parameters (Table 2 to Table 4).

Table 2. The auto regression equation (1) parameters for Uttar Pradesh and Gujarat

| **Most Affected States** | **Uttar Pradesh** | | | **Gujarat** | | |
|---|---|---|---|---|---|---|
| Parameter | First Wave | Second Wave | Third Wave | First Wave | Second Wave | Third Wave |
| Constant | -0.0020633 | 8.9723e-05 | -0.00021476 | 0.001393 | 0.00016 | -0.000008 |
| $\emptyset_1$ | 0.47478 | 0.94536 | 1.3249 | 1.1634 | 1.3645 | 1.1943 |
| $\emptyset_2$ | 0.31327 | 0.34101 | -0.49343 | -0.23753 | -0.13255 | -0.14335 |
| $\emptyset_3$ | 0.19676 | 0.12799 | 0.65395 | 0.075313 | -0.18608 | 0.014541 |
| $\emptyset_4$ | 0.052774 | -0.54624 | -0.50665 | -0.028793 | 0.18139 | -0.20225 |
| $\emptyset_5$ | -0.051238 | 0.12111 | -0.0029268 | -0.002703 | -0.23422 | 0.1096 |

Table 3. The auto regression equation (1) parameters for Jammu Kashmir and Punjab

| **Moderately Affected States** | **Jammu and Kashmir** | | | **Punjab** | | |
|---|---|---|---|---|---|---|
| Parameter | First Wave | Second Wave | Third Wave | First Wave | Second Wave | Third Wave |
| Constant | -0.00063 | -0.00043 | 0.00046 | 0.0014106 | 0.00009 | -0.00013 |
| $\emptyset_1$ | 0.58038 | 0.65966 | 0.78683 | 0.56658 | 0.73516 | 0.80801 |
| $\emptyset_2$ | 0.20061 | 0.37627 | 0.24047 | 0.42664 | 0.35069 | 0.47417 |
| $\emptyset_3$ | 0.17848 | 0.04997 | 0.3158 | -0.00504 | 0.23919 | -0.11632 |
| $\emptyset_4$ | 0.03045 | 0.01791 | 0.01462 | -0.02349 | -0.21329 | -0.14095 |
| $\emptyset_5$ | -0.03297 | -0.11724 | -0.4015 | 0.0065003 | -0.1199 | -0.05471 |

Table 4. The auto regression equation (1) parameters for Arunachal Pradesh and Meghalaya

| **Least Affected States** | **Arunachal Pradesh** | | | **Meghalaya** | | |
|---|---|---|---|---|---|---|
| Parameter | First Wave | Second Wave | Third Wave | First Wave | Second Wave | Third Wave |
| Constant | -0.003738 | -0.00050 | 00.001274 | -0.005735 | -0.000486 | 0.002314 |
| $\emptyset_1$ | 0.2801 | 0.17706 | 0.37887 | 0.53583 | 0.48029 | 0.49737 |
| $\emptyset_2$ | 0.20757 | 0.20909 | 0.22586 | -0.012667 | 0.36361 | 0.50707 |
| $\emptyset_3$ | 0.12085 | 0.31756 | 0.3826 | 0.27396 | 0.01082 | 0.12418 |
| $\emptyset_4$ | 0.12204 | 0.24922 | 0.25065 | 0.016984 | 0.026446 | 0.12133 |

| | | | | | | |
|---|---|---|---|---|---|---|
| $\emptyset_5$ | 0.22934 | 0.027931 | -0.29739 | -0.009643 | 0.09758 | -0.28506 |

For each of the most affected, moderately affected & least affected states, Root mean square error (RMSE) has been calculated that shows that prediction of third wave using Auto Regression model is more close to the real data with less error for most of the cases except Gujarat. Also, RMSE is high for second wave of Uttar Pradesh that suggests a little more introspection to the AR model is required.

Further the correlation between actual and predicted data has also been calculated for all the three waves. The results showed in Table 5, gives an impression that the correlation coefficient between actual and predicted (CC) is acceptable for all the three waves except for first wave of Meghalaya.

Table 5. RMSE and Correlation Coefficient between actual and prediction values for a training period

| States | | Parameters | First Wave | Second Wave | Third Wave |
|---|---|---|---|---|---|
| Most Affected | Uttar Pradesh | RMSE | 394.7311 | 1094.3113 | 487.0353 |
| | | CC | 0.9725 | 0.9909 | 0.9927 |
| | Gujarat | RMSE | 45.2707 | 347.5947 | 879.4328 |
| | | CC | 0.9740 | 0.9950 | 0.9806 |
| Moderately Affected | Jammu and Kashmir | RMSE | 122.2006 | 193.7972 | 243.3526 |
| | | CC | 0.9309 | 0.9844 | 0.9844 |
| | Punjab | RMSE | 175.8681 | 234.6167 | 342.7063 |
| | | CC | 0.9610 | 0.9939 | 0.9816 |
| Least Affected | Arunachal Pradesh | RMSE | 40.6637 | 47.3334 | 45.1335 |
| | | CC | 0.8767 | 0.9461 | 0.9107 |
| | Meghalaya | RMSE | 39.9605 | 65.9510 | 23.4782 |
| | | CC | 0.6950 | 0.9601 | 0.9654 |

## 5.2 Graphical Results

The graph is plotted between the days of each wave duration on x-axis and the number of confirmed cases on y-axis for all the six states viz. Arunachal Pradesh, Meghalaya, Jammu & Kashmir, Punjab, Gujarat and Uttar Pradesh. In case of most affected states namely Gujarat and Uttar Pradesh, the auto regression models give a fairly acceptable prediction for all the three waves (Figure 1). Further, we observe that in case of moderately affected states namely Jammu & Kashmir, Punjab, the auto regression models doesn't give a good prediction for first wave but the AR models developed for second and third shows a close fit for the prediction (Figure 2). It is observed that the auto regression models doesn't give a good prediction for first & second waves in case of least affected states: Arunachal Pradesh, Meghalaya but shows a moderately good fit for the third wave prediction (Figure 3).

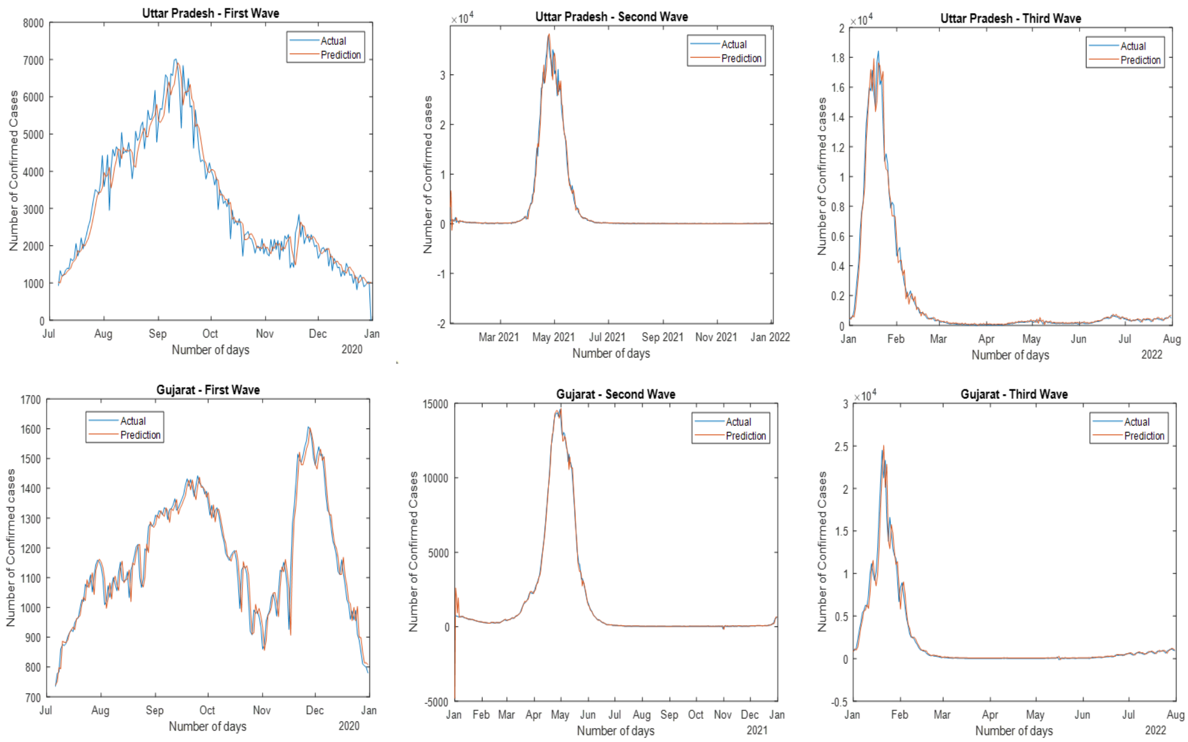


Figure 1. Comparison between actual data and prediction data for Uttar Pradesh and Gujarat using AR model.

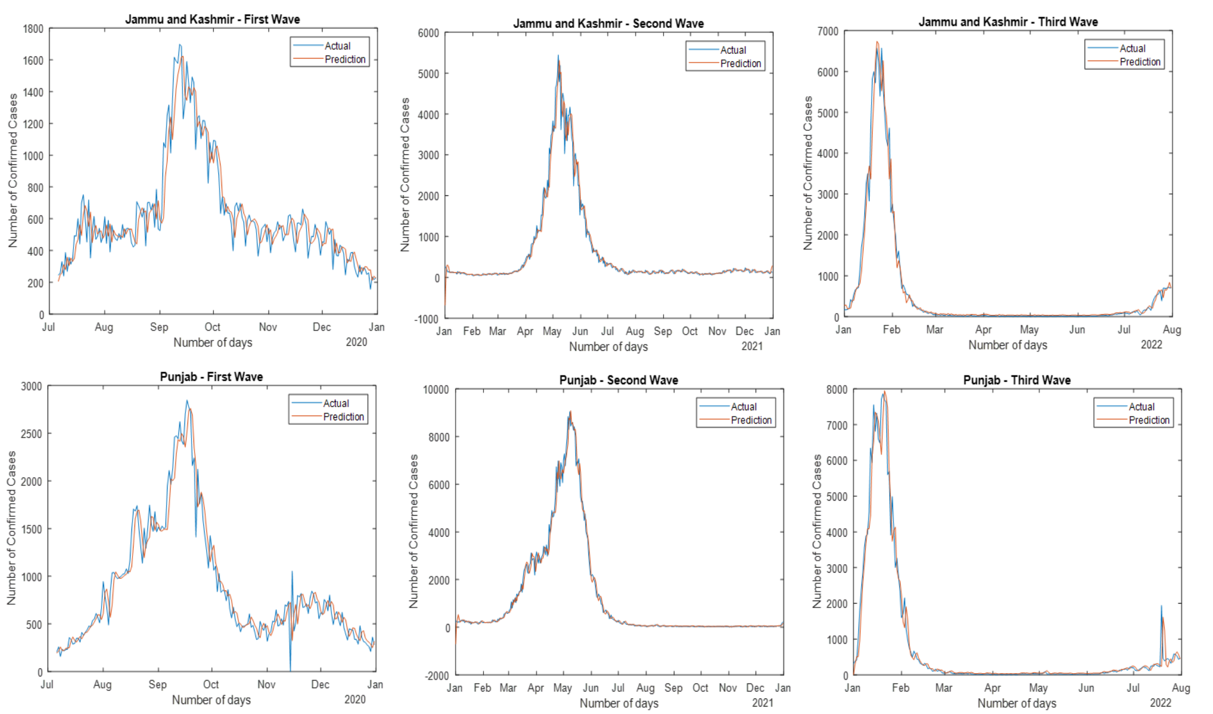


Figure 2: Comparison between actual data and prediction data for Jammu Kashmir and Punjab using AR model

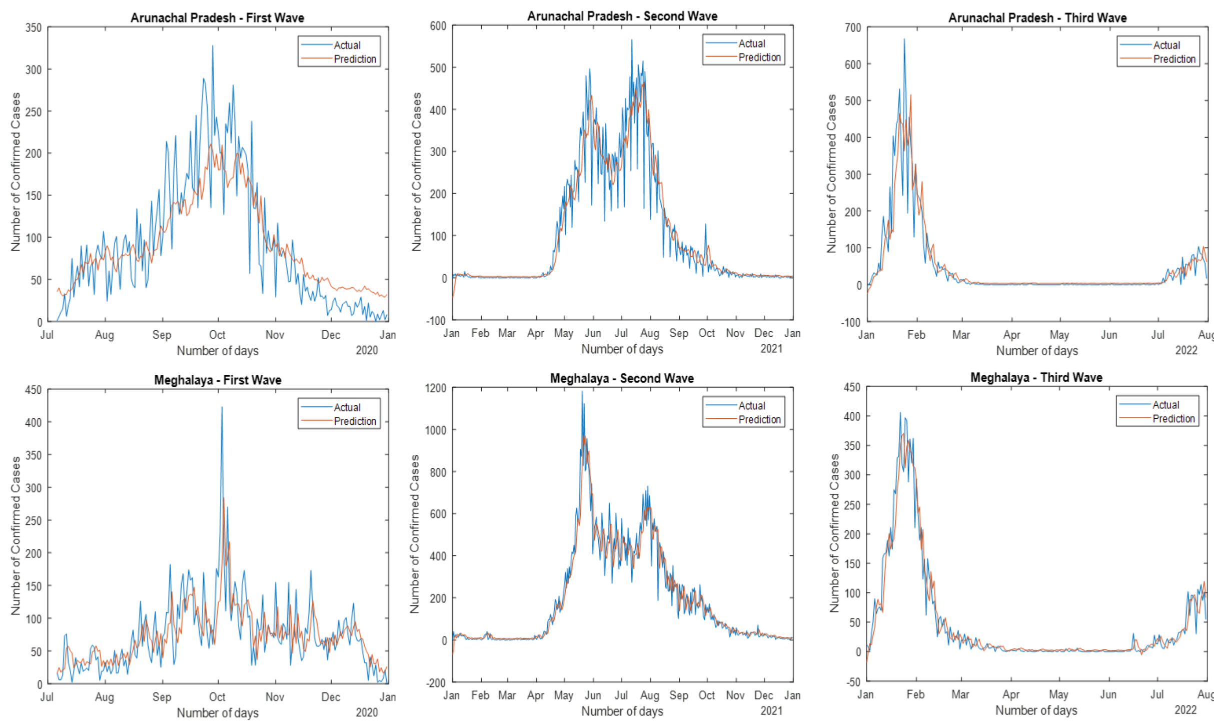


Figure 3. Comparison between actual data and prediction data for Arunachal Pradesh and Meghalaya using AR model

### 5.3 Proposed Improvements

The above numerical results and graphical results can be further improved with the help of different lags and also finding the error polynomials. The analysis of the same implies that the linear multiple auto regression model is not enough to cover the variability of the data. Further plan is to look at the possibility of using ANN to extract the non-linearity between the data if it exists. In continuation, plan is there to execute an hybrid model to capture the linear and non-linear parts of the data.

### 5.4 Validation

The AR models are developed by bifurcating the data into three waves for each state i.e. From 1st July 2020 to 31st December 2020 data considered as first wave, 1st January 2021 to 31st December 2021 data as second wave and 1st January 2022 to 31st July 2022 data as third wave. These models are trained for 85% , 94%, 87% of the data for first, second and third wave respectively and tested for 15%, 6% & 13% of the data for each wave in order. Further, the models are used for prediction of COVID confirmed cases for the month of July 2022 in six identified states of India. The results show that the error is more in the models created for first & second waves of each state whereas the errors reduces when it comes to the prediction of third wave with a correlation of 0.87. Hence it is expected that the development of ANN models might work better for the cases where the error is more. Also, it is suggested that a hybrid model approach where AR models taking linearity into account integrated with ANN models to capture the non-linearity in data can be developed.

## 6. Conclusion

This study identifies the most affected, moderately affected & least affected states of India and choose 2 states (Arunachal Pradesh and Meghalaya as least affected states, Punjab & Jammu-Kashmir as moderately affected states, Gujarat & Uttar Pradesh as most affected states) of India in each category for further analysis. Auto Regression models are developed for each state under each category for all the three waves. Further the confirmed cases for fourth COVID wave are predicted using these models for the fourth wave. The results obtained are moderate and needs some finer tuning or maybe a different approach for better prediction.

## Hypothesis testing

The following table explains the hypothesis on data being stationary or not (Table 6).

Table 6. Hypothesis testing using Kwiatkowski–Phillips–Schmidt–Shin (KPSS) tests
With 5 days lag and 95% Significance Level

| Null Hypothesis: Confirmed cases is Trend Stationarity | | | | | |
|---|---|---|---|---|---|
| States | | Hypothesis Testing | First Wave | Second Wave | Third Wave |
| Most Affected | Uttar Pradesh | Null Rejected | True | True | True |
| | | Test Statistics | 0.5563 | 0.3869 | 0.3756 |
| | Gujarat | Null Rejected | True | True | True |
| | | Test Statistics | 0.2839 | 0.4550 | 0.3724 |
| Moderately affected | Jammu and Kashmir | Null Rejected | True | True | True |
| | | Test Statistics | 0.5070 | 0.5730 | 0.2951 |
| | Punjab | Null Rejected | True | True | True |
| | | Test Statistics | 0.4830 | 0.5997 | 0.4061 |
| Least affected | Meghalaya | Null Rejected | True | True | True |
| | | Test Statistics | 0.6815 | 1.1755 | 0.3441 |
| | Arunachal Pradesh | Null Rejected | True | True | True |
| | | Test Statistics | 0.5260 | 1.1557 | 0.4120 |

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