OPEN ACCESS Freely available online

Geography & Natural Disasters

Research Article

Mapping of Covid-19 Pandemic in India using Interpolation Method Based on GIS

Venkatesan Selvaraj*

Department of Geology, The National College, Tiruchirappalli, Tamil Nadu, India

ABSTRACT

The first outbreak of COVID-19 pandemic in Wuhan, China was proclaimed on 31st December 2019. The outbreak has spread expeditiously all over Chinese cities and several countries worldwide. We describe the Spatio-temporal pattern and measure the spatial association of the early stages of the COVID-19 epidemic in India from March to April. In this study, the detailed discussion of Corona cases and major hotspot places in India was given. Analysis of spatial distribution patterns may provide valuable information to support government monitoring and predicting spread of the virus across small and large areas. To inform researchers and program developers, this mapping review presents the scope and depth of the Geographic Information System (GIS) and spatial analysis studies conducted by COVID-19 in India. In particular, GIS and spatial analysis can be essential tools for knowledge, prevention and treatment of diseases. For example, GIS technology can be used as a visualization help to map the geographical distribution of the disease, the potential risk factors and the resources available for treatment and prevention. In relation to the spatial analysis of certain information, it is possible to evaluate the risks of disease, trends in outbreaks over time and space, and hotspots of infection as a result; a GIS-based spatial distribution using the Inverse Distance Weighted (IDW) method was performed in this article to identify potential disease risk assessments in India.

Keywords: COVID-19, Spatio-temporal analysis, GIS, IDW, India, Prediction, Spatial Distribution.

INTRODUCTION

In 21st century a major challenge we are facing is the emerging infectious disease. The evolving new coronavirus (COVID-19) pneumonia outbreak is turned into a global public health crisis. The COVID-19 outbreak is decidedly kindred to the severe acute respiratory syndrome (SARS) the outbreak that occurred in 2003; both outbreaks were engendered by new coronavirus during time periods coinciding with the Chinese Spring Festival. In December 2019, a newly identified β-coronavirus caused a cluster of pneumonia cases in Wuhan, China. On 12 January 2020, the coronavirus was initially named as the 2019- novel coronavirus (2019-nCoV) by World Health Organization (WHO).

On 26th January 2020, as of 6:00 p.m. Beijing time, there are more than 2000 confirmed cases worldwide with a greater number from Hubei province. Both the Coronavirus Study Group (CSG) of the International Committee and WHO has officially named the disease as SARS-CoV-2 and coronavirus disease 2019 (COVID-19), issued on 11 February 2020. Within a short period of time, the Chinese scientists have rapidly isolated a SARS-CoV-2 from a patient on 7 January 2020 and emerged as genome sequencing of the SARS-CoV-2 (Lu, 2020). The first solid evidence for human-to-human transmission of SARS-CoV-2 was come up with the unprecedented study conducted in the city of Shenzhen near Hong Kong by a group of clinicians and scientists from the University of Hong Kong (Chan, 2020, Li, 2020 and Riou, 2020).

Ensuing, the contagion can spread from human to human (Imai, et al., 2020, Wang, et al., 2020 and Huang, et al., 2020), for example, In Guangdong Province during the family gatherings, there have been sundry cases of human-to-human transmission was recorded (Health Commission of Guangdong Province, 2020) and in the premature stage of the outbreak several healthcare workers were diagnosed. Withal, the coronavirus can

Correspondence to: Venkatesan Selvaraj, Department of Geology, The National College, Tiruchirappalli, Tamil Nadu, India, Tel: 9788886224; E-mail: gssvenkat88@gmailo.com

Received: May 10, 2020; **Accepted:** August 27, 2021; **Published:** September 06, 2021

Citation: Selvaraj V (2021) Mapping of Covid-19 Pandemic in India using Interpolation Method Based on GIS. J Geogr Nat Disas. 11:p366.

exist and hold on in an environment and on the surface of objects for up to 14 days (Read et al., 2020). The levitate population, i.e., the seasonal and temporary non-resident population is a possible carrier for virus transmission (Chen, et al., 2020 and Shen, et al., 2020). On 30 January 2020, India's first case of 2019-20 coronavirus pandemic was reported, originating from China. The Ministry of Health and Family Welfare have ensured a total of 23,651 cases, 8,324 recovered (including 1 migration) and 1,074 deaths in the country as of 30 April 2020 (www.mohfw.gov.in. April 2020). A nationwide lockdown for 21 days was announced by the prime minister on 24 March to the entire 1.3 billion population of India and it was extended until 3rd May on 14 April 2020.

The GIS is the structured combination of hardware, software, spatial data and human resources formulate to capture, store, standardize, manipulate, analyze and display geographically referenced particulars to enable complex planning and geographical management (Rytkonen, 2004 and Duncombe, 2012). GIS are tools that permit users to depict maps, analyze spatial information, improve the data, present and swap the results of these operations in scientific studies that point to show the geographic behaviour of a disease or inspect health indicators. Recently, Geographical Information Systems (GIS) have emerged as a generative and chief component tool in the supervision of many projects in public health and epidemiology, particularly in transmissible diseases (Rytkonen, 2004 and Ratmanov, et al., 2013).

To inform researchers and program developers, this mapping review presents the scope and depth of the GIS and spatial analysis studies conducted by COVID-19 in India. In particular, GIS and spatial analysis can be essential tools for knowledge, prevention and treatment of diseases. For example, GIS technology can be used as a visualization help to map the geographical distribution of the disease, the potential risk factors and the resources available for treatment and prevention. In relation to the spatial analysis of certain information, it is possible to evaluate the risks of disease, trends in outbreaks over time and space, and hotspots of infection. Therefore, in this study, we explored the spatial distributions of the COVID-19 epidemic in India to reveal the potent changes and trends in reported cases using GIS software. These results will come up with beneficial information for preventing disease at both the individual and organization levels.

AREA OF STUDY

India is a country located in South Asia. It is the second-most populous country and the most populous democracy in the world. Surrounded by the Indian Ocean on the south, the Bay of Bengal on the southeast and the Arabian Sea on the southwest, the land borders shares with China, Nepal, and Bhutan to the north, Pakistan to the west, Bangladesh and Myanmar to the east. The coordinates are from 8°4' N to 37° 6' N latitude and 68° 7' E to 97° 25' E longitude. New Delhi is the Capital of India and the major cities in the nation are Mumbai, Delhi, and Kolkata. In the list of countries by population India ranks number 2. The population density in India is 464 per km2 and 35.0 % of the population is urban (Figure 1 and Table 1).

Figure 1: Distribution of population in India.

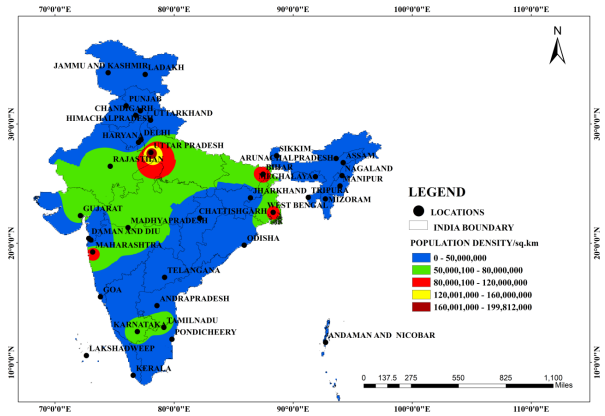


Table 1: State wise population (2011).

S. No	States/ Union Territory	Population Density/ sq.km	S. No	States/ Union Territory	Population Density/ sq.km
1	Andaman and Nicobar	46	19	Maharashtra	365
2	Andra Pradesh	308	20	Manipur	122
3	Arunachal Pradesh	17	21	Meghalaya	132
4	Assam	397	22	Mizoram	52
5	Bihar	1102	23	Nagaland	119
6	Chandigarh	9252	24	Odisha	269
7	Chattisgarh	189	25	Pondicherry	2598
8	Daman And Diu	2169	26	Punjab	550
9	Delhi	11312	27	Rajasthan	201
10	Goa	394	28	Sikkim	86
11	Haryana	573	29	Tamilnadu	555
12	Himachal Pradesh	123	30	Tripura	350
13	Jammu and Kashmir	124	31	Uttar Pradesh	828

14	Jharkhand	414	32	West Bengal	1029
15	Karnataka	319	33	Gujarat	308
16	Kerala	859	34	Ladakh	5
17	Lakshadweep	2013	35	Uttarkhand	189
18	Madhya Pradesh	236	36	Telangana	307

METHODOLOGY

In the present research work, many peer-reviewed research papers on the topic of COVID-19 related to health conditions, preventive facilities and in many medical fields have been reviewed. In this study, the distribution of coronavirus has been mapped spatially for all over India. The use of GIS and spatial analysis approaches were ambiguously defined for the uses of this analysis in order to obtain a diversity of emerging activities, i.e. they included research papers using any specialized GIS software or explicitly implementing any spatial analysis techniques (Shankar and Kawo, 2019; Balamurugan et al., 2020). Many government agencies and health officials have mapped the corona positive cases, mortality and recoveries to recognize where COVID-19 infections have occurred by using GIS capabilities such as spatial analytic mapping. In interpolation technique, the Inverse Distance Weighted is the most widely used method for mapping any pandemic diseases. Time-enabled maps can unveil how the disease is getting outspread over time and where you desire to plan interventions. COVID-19 inordinately influences certain demographics such as the aged and those with basal health conditions. Inverse distance weighted (IDW) interpolation has clearly made the supposition that things which are close to each other are more identical than those that are farther apart. To envision a value for any unmeasured position, IDW uses the measured value adjoining the prediction location. The measured values proximate to the prediction location have more impact on the predicted value than those farther away. IDW surmise that each measured point has a local influence that reduces with distance. It gives considerable weights to points closest to the prediction position, and the weight reduces as a function of distance, hence the name inverse distance weighted. Utilizing the IDW spatial interpolation technique in Arc GIS Software several thematic maps were produced (Srivastava et al., 2012). The GIS tools were used to illustrate the distributions pattern of coronavirus and forecasts the number of patients increasing per each day by the aid of Inverse Distance Weighted, Interpolation technique. For any infectious disease outbreak especially during pandemics such as Coronavirus disease, the geographic apprehension is very crucial in reconnaissance and counteract this deadly virus.

The state-wise COVID-19 data of India were collected from the Health Ministry and Government of India as per 30th April 2020. These data are were illustrated as a different thematic map showing the distribution of infectious spread and trend of COVID-19 using spatial analysis tool by ArcGIS software version 10.2. The prediction of COVID-19 positive cases was done for the month of May and June using linear regression formula for the forecast in excel which is the simple and effective way to illustrate the transmission of the virus (John, 2013). Mathematically, the following equation will expound the linear regression formula:

$$Y = bx + a$$

Where:

X is an independent variable

Y is a dependent variable

a is the y-intercept, which is the expected mean value of y when all x variables are equal to 0.

b is the slope of a regression line, which is the rate of change for y as x changes.

RESULTS AND DISCUSSIONS

Corona Pandemic Ongoing Status in India

As per 30th April 2020 the total positive corona affected persons in India is 23,651 cases, 8,324 recovered and 1,074 deaths (Table 2). The outbreak has been proclaimed as a global epidemic in numerous states and union territories. Due to this pandemic, several educational institutions and many commercial establishments have been abandoned. As most of the corona positive cases were associated with other countries, India has suspended all tourist visas. The government of India has announced lockdown for 82 districts in 22 states and Union Territories of the country where coronavirus cases have been reported till 31 March, on 22 March 2020 and now it has been extended up to 3rd May. On March 2020, the ministry of health and family welfare declared a mandatory screening of all international passengers visiting India.

Table 2: COVID-19 State wise status in India.

S. No	States/ Union Territory	Confirmed cases	Recovered cases	Death cases
1	Andaman and Nicobar	33	15	0
2	Andra Pradesh	1332	287	31
3	Arunachal Pradesh	1	1	0
4	Assam	38	29	1
5	Bihar	392	65	2
6	Chandigarh	56	17	0
7	Chattisgarh	38	34	0

8	Daman and Diu	0	0	0
9	Delhi	3439	1092	56
10	Goa	7	7	0
11	Haryana	310	209	3
12	Himachal Pradesh	40	25	1
13	Jammu and Kashmir	581	192	8
14	Jharkhand	107	19	3
15	Karnataka	535	216	21
16	Kerala	495	369	4
17	Lakshwadeep	0	0	0
18	Madhya Pradesh	2561	461	129
19	Maharashtra	9915	1593	432
20	Manipur	2	2	0
21	Meghalaya	12	0	1
22	Mizoram	1	0	0
23	Nagaland	0	0	0
24	Odisha	125	39	1
25	Pondicherry	8	3	0
26	Punjab	357	90	19
27	Rajasthan	2438	768	51
28	Sikkim	0	0	0
29	Tamilnadu	2162	1210	27
30	Tripura	2	2	0
31	Uttar Pradesh	2134	510	39
32	West Bengal	758	124	22
33	Gujarat	4082	527	197
34	Ladakh	22	16	0
35	Uttarkhand	55	36	0
36	Telangana	1012	367	26
	Total	23651	8324	1074

Maharashtra is the most affected state in India, followed by Gujarat, Delhi, Madhya Pradesh and Rajasthan. As per 30th April 2020 Maharashtra (9915), Gujarat (4082), Delhi (3439), Madhya Pradesh (2561), Rajasthan (2438), Tamil Nadu (2162) and Uttar Pradesh (2134) has been recorded as a highly risky States by Health Ministry and Government of India (Figure 2 and Table 2). Nagaland and Sikkim have secured no positive corona cases up to date. The total recovered patients in India 8324 cases among which Goa (7), Manipur (2), Tripura (2), Arunachal Pradesh (1), Pondicherry (3) and Kerala (369) are the states having a greater number of patients cured/recovered from coronavirus in India (Figure 3 Table 2). Kerala is the first state produced a greater number of recovered patients when compared to other states, as Kerala is having a total number of positive cases of 495 corona affected patients, in that they have cured 369 persons. The total mortality rate in India is 1074 persons among which Maharashtra 432, Gujarat 197 and Madhya Pradesh 129, Delhi 56 has the highest mortality rate as per data on 30th April 2020 (Figure 4 and Table 2).

Figure 2: Distribution of estimated confirmed patients.

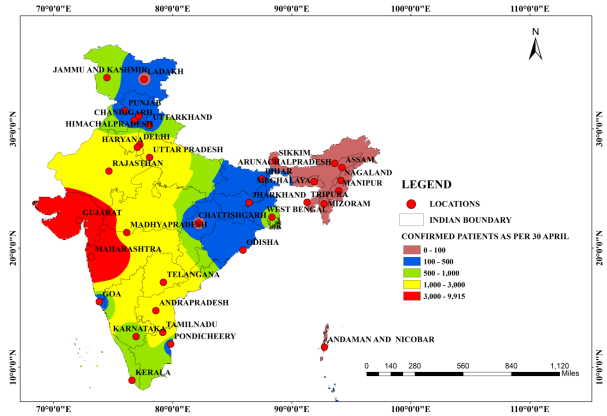


Figure 3: Distribution of estimated cured/ recovered patients.

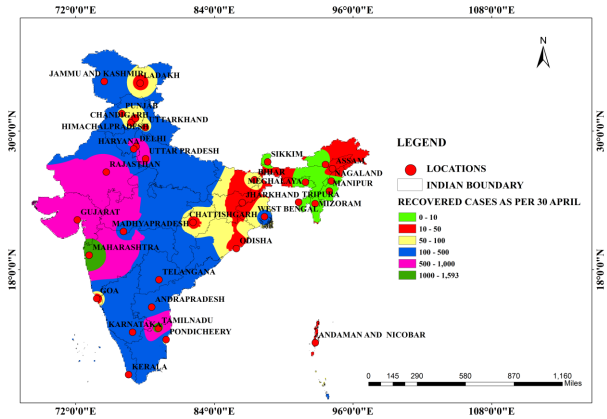
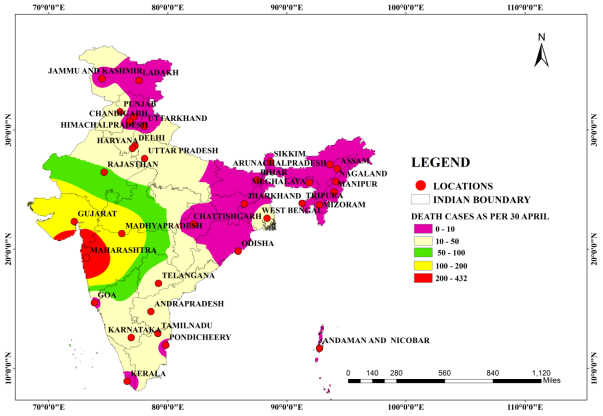


Figure 4: Distribution of estimated Death cases.



Interpolation method using IDW has been obtained with the aim of predicting the spread of disease in India. This map shows the number of patients and the extended disease zone across the country. As per IDW, the pattern of COVID-19 positive cases is classified as 5 classes ranging from is 0 to 100, 100 to 500, 500 to 1000, 1000 to 3000 and 3000 to 9915 shown in (Figure 2 and Table 2). These classes in the map represent the distribution of estimated positive Corona cases confirmed in different states of India. The highest number of spread ratios of positive cases was found in states such as Maharashtra (9915), Gujarat (4082) and Delhi (3439) which is classified as the range of 3000 to 9915 represented in red colour as a risky state.

The second-highest number of spread ratio of positive confirmed cases were observed in the following states such as Madhya Pradesh (2561), Rajasthan (2483), Tamil Nadu (2162), Uttar Pradesh (2134), Andra Pradesh (1332) and Telangana (1012) are the states with the range of 1000 to 3000 represented as a threatening states which is about to exposed to the risky stage which is indicated in yellow colour. The Moderate spread ratio was observed in the following State such as West Bengal (758), Jammu and Kashmir (581), Karnataka (535), Kerala (495), Bihar (392), Punjab (357), Haryana (310), Odisha (125) and Jharkhand (107) are classified into two ranges from (1000 to 500) to (500 to 100) and indicated by green and blue in colour. The lowest spread ratio is observed in the following states such as Chandigarh (56), Uttarkhand (55), Himachal Pradesh (40), Assam (38), Chattishgarh (38), Andaman and Nicobar (33), Ladakh (22), Meghalaya (12), Pondicherry (8), Tripura (2) and Manipur (2) with the range of (0 to 100) indicated by green colour. Arunachal Pradesh and Mizoram are the sates having only one positive case. Sikkim and Nagaland are the states which was reported as zero positive cases in India is also lying in the same range of categories from 0 to 100 which is depicted as the risk-free states.

So far, 8324 peoples have been cured and recovered from hospitals in India as per 30 April 2020. As per IDW map of estimated Cured/Recovered patients in India, the following states have the highest ratio of recovered cases such as Goa (7), Manipur (2), Tripura (2), Arunachal Pradesh (1), Pondicherry (3) and Kerala (369). This recovered ratio is classified into 6 classes according to their progress in recovering from this infectious disease with the range of (0 to 10), (10to 50), (50 to 100), (100 to 500), (500 to 1000) and (1000 to 1593) illustrated in different colours from dark green to light green based on their respective values and distribution (Table 2 and Figure 3).

The total number of corona death cases in India has reached 1074. Maharashtra (432), Madhya Pradesh (129) and Gujarat (197) has been reported as the highest mortality state as per data on 30 April 2020. Sikkim and Nagaland are the states having no corona active cases up to date. Followed by this, Goa, Tripura, Arunachal Pradesh and Manipur are reported as no positive cases since all the patients have been recovered and reported negative. As per the IDW map of estimated death cases in India the trend of death rate is given and classified into 5 classes with the range of (0 to 10), (10 to 50), (50 to 100), (100 to 2000 and (200 to 432) according to their distribution in mortality rate indicated by various colours from pink to red (Figure 4 and Table 2).

Major Hotspots in India

The government has declared and classified every state into a hotspot zone based on its contagious level. Of India's 736 districts, 207 districts were non-hotspots and 170 were spotted as hotspot zones defining the places with a minimum of 15 confirmed cases or where there was an aggressive rise in cases (Health Ministry of India). The government of India has categorized the hotspots into 3 zones namely red zone, orange zone and green zone (Figure 5). The districts lying in the red zones are the major hotspot areas with more outbreaks of corona cases. Orange zone includes the states having few coronavirus cases or the states getting recovered from the corona cases will also lie in the orange zone. The districts having no corona cases will come under green zones. These zones were created to focus on the states having a higher growth rate of infection.

Figure 5: COVID-19 Hotspots in India.

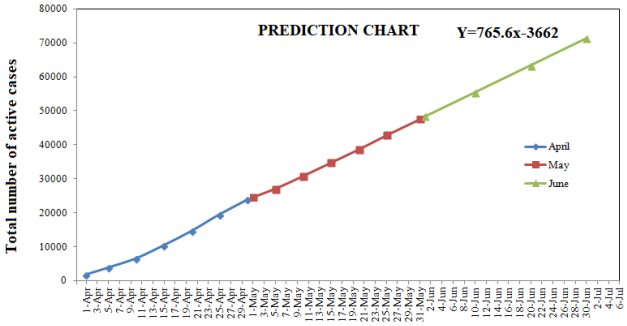
Prediction of Active Cases

Forecasting is a special technique of making predictions for the future by using historical data as inputs and analyzing trends. To forecast confirmed cases of COVID-19, we adopt simple time series forecasting approaches. The prediction is done using Linear regression formula for the forecast in excel which is a simple and effective way (Jai keida et al., 2013). In statistical modeling, linear regression analysis is used to estimate the relationships between two or more variables. Linear Regression analysis helps you understand how the dependent variable changes when one of the independent variables varies and allows you to mathematically determine which of those variables really has an impact. This has shown good forecast accuracy over several forecasting competitions and is especially suitable for short series. However, this model helps in illustrating, how quickly a highly contagious virus can spread and get out of control.

The total infected cases of COVID-19 have progressively increased for the past 2 months from February to March. The data refers to daily cumulative cases and covers the period from

April 1 to April 30 which is used as the input for prediction. At the starting of April, the total infected case is reported as 1792. By using the regression method, the prediction is carried out for the month of May and June. The total active case at the end of April is reported as 23,651 by the Ministry of Health and Family Welfare, Government of Tamil Nadu. From our forecasting method, it is calculated that at the end of the may, India will be reaching 47,546 infected active cases and at the end of June, it is expected to be increased up to 71,234 corona active cases. From the graph, it is clear that the trend line is very smooth and showing a gradual increase in values. The active cases for the April month are shown in the blue line. The predicted positive cases for the month of May and June are given in red and green line (Figure 6). So, if we proceed with this method for predicting the cases for the month of July it is estimated that it will exceed more than one lakh infected persons at the end of the month. People's support and contribution play a vital role in suppressing the spread of infection and social distancing is the only way to combat the coronavirus. World Health Organisation Report says, that one person affected with this pandemic can infect hundreds other in a matter of a week to 10 days. The government has suggested the peoples to follow the social distancing and to stay at the home to break the chain of its transmission. We hope that our forecasts will be a useful tool for governments and individuals towards making decisions and taking the appropriate actions to contain the spreading of the virus to the degree possible.

Figure 6: Prediction graph for COVID-19 active cases.



CONCLUSIONS

COVID-19 is characterized by a long incubation period, strong infectivity and difficulty of detection, which has led to a sudden outbreak and the rapid development of an epidemic. This situation requires GIS technology to allow rapid responses and analyses, quick supply of information about the epidemic. In this study, we analyzed the spatial representation of the disease, population and the major hotspot areas all over India using Interpolation tools such as IDW. The outcome of this result may provide useful information for the public and government monitoring and in predicting of the distribution level of this infectious disease. Several attempts were made to provide information on ongoing corona status in India, including positive cases, cured/ recovered and mortality rate through IDW. This study implies an attempt for the prediction of raise of active corona positive cases in the future using linear regression formula for forecasting. The prediction is done for the month of May and June. This prediction doesn't tell the future exactly, it only shows a probability. As the real-time data changes daily, the predictions will also change accordingly. We hope this data will help our government to monitor the spread of COVID-19 infected cases in India. In assessing the contribution of GIS technology to the containment of the COVID-19 epidemic, it is clear that many challenges remain to be studied. Although more data are needed to have a more detailed prevision about the spread of the virus and the number of confirmed cases is still increasing. For further comparison or for future perspective, case definition and data collection must be maintained in real-time. However, the study has been carried out by limited data available up to 30 April 2020 and thereby a large number of data were required for future research. Finally, the result derived in this study may help in the reference for government monitoring decision-makers for improving the mitigation and prediction of COVID-19.

REFERENCES

1. Balamurugan P, Kumar P. S, Shankar K. Dataset on the suitability of groundwater for drinking and irrigation purposes in the Sarabanga River region, Tamil Nadu, India, Data in brief. 2020; 29: 105-255.
2. Chan J.F.W, Yuan S, Kok K.H, To K.K.W, Chu H, Yang J, Xing F.F, Liu J.L, Yip C.C.Y, Poon R.W.S, et al. A familial cluster of pneumonia associated with the 2019 novel coronavirus indicating person-to-person transmission: A study of a family cluster. Lancet. 2020; 395: 514–523.
3. Duncombe J, Clements A, Hu W, Weinstein P, Ritchie S, Espino FE. Geographical information systems for dengue surveillance. Am J Trop Med Hyg. 2012; 86: 753-755.
4. Health Commission of Guangdong Province. Epidemic Situation of the Novel Coronavirus in Guangdong Province Published on 23 January 2020.
5. Home, Ministry of Health and Family Welfare GOI". www.mohfw.gov.in. Retrieved 20 April 2020.
6. Jai keida, Syndar, S., Paster, D.R., 2013. Sales forecasting using regression and artificial neural networks.
7. John B Guerera. 2013. Regression analysis and forecasting, models mckinley capital management LLC.
8. Kawo N. S, Shankar K. Groundwater quality assessment using water quality index and GIS technique in Modjo River Basin, Central Ethiopia. Journal of African Earth Sciences. 2018; 147: 300-311. DOI:
9. Li Q, Guan X, Wu P, Wang X, Zhou L, Tong Y, et al. Early Transmission Dynamics in Wuhan, China, of Novel Coronavirus-Infected Pneumonia. N Engl J Med, 2020.
10. Lu R, Zhao X, Li J, Niu P, Yang B, Wu H, et al. Genomic characterisation and epidemiology of 2019 novel coronavirus: implications for virus origins and receptor binding. Lancet. 2020; 395(10224): 565–74.