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Spatial distribution and impact assessment of COVID-19 on human health using geospatial technologies in India

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Abstract
The economy of any country depends on its human resources. Currently, the 2019 novel coronavirus disease (COVID-19) is the most affecting infectious disease. The number of active cases and deaths are still increasing in India. COVID-19 has affected human life, socio-economic development and national relations up to a great extent. It is a risk for senior citizens and people with several health issues such as cancer, diabetes, heart related problems. The World Health Organization (WHO) has formally declared COVID-19 to be a public health emergency in global level. As of 6th May 2020 Maharashtra, was found to be the most affected state in India followed by Gujarat and Delhi. Due to the infection chain ratio, the positive cases are increasing each day in each affected states of India. Indian government tried the lockdown concept to break the infection chain ratio affected by COVID-19. The aim of the research is to analyze the spatial distribution and Impact assessment of the COVID-19 for human health using GIS software. Geographic Information Systems (GIS) technologies have played an important role in the spatial information, spatial tracking of confirmed cases, active case, death and discharge case as well as prediction of magnitude of the spread. Therefore, monitoring and planning using geospatial analysis is very important to control COVID-19 spread in the country.

Keywords: COVID19, geographical information systems, spatial tracking, human resources

Introduction

The spread of pandemic Covid-19 corona virus has been the most deadly, causing infection to more than 3,059,642 people around the world, out of which 211,028 are confirmed to be dead on 30th of April 2020 (WHO, 2020). The outbreak caused from a laboratory in Wuhan city, China during December 2019. It soon started spreading throughout the corners of the world. Apart from China, Italy and America were among the most affected countries from the novel corona virus having a number of 1,064,737 and 203,591 confirmed cases with 61,670 and 27,682 deaths respectively [1]. In India, the spread of infection is less as compared to the countries like America and Italy. But, the numbers of confirmed cases are rising each day with a count of 33,362 positive cases with 1082 deaths by 30th April 2020. In India, Maharashtra is the highly affected state with the positive cases up to 9915 with 432 deaths followed by Gujarat and Delhi i.e., 4082 and 3439 positive cases with 197 and 56 deaths respectively. Madhya Pradesh has the 4th highest positive cases i.e., 2560 with highest death rate i.e., 130 as compared to the death cases in relation to the positive cases of other states [2]. The corona virus is not only affecting people around the world, but also, it is affecting the world's economy. Due to the pandemic, it is necessary to stay inside the house as a preventive measure. As the virus is capable of spreading from person to person, gatherings and crowds are completely banned as per the government's guidelines. According to the instructions of the Indian government, a lockdown has been initiated, where all the citizens are advised to stay inside their respective homes except for the medical teams, police and security staffs as well as the cleaners. As the infection spreads from person to person, this lockdown has been proved to be effective in breaking the infection chain up to a great extent. The main aim behind the lockdown is to slow down the rate of spread of infection among the people, so that there will not be a sudden rise in the infection rate, which will surpass the number of beds in the hospitals. Human resources are mainly getting affected as the workers and employees are not being able to go to work as a result, the socio-economic development is being hampered mostly. There are many corporate sectors which run in relation with foreign countries are affected much. Apart from the businesses, people working as daily wage labors are prone to this disease the most along with their own poverty because during lockdown, they have no work to do, as a result, they have least or no money to survive. This virus mostly attacks the people having poor immunity, senior citizens as well as kids and the people having health issues such as diabetes, severe heart problems, respiratory and lung problems [3].

Corona virus is grouped under Severe Acute Respiratory Syndrome (SARS). SARS-CoV-2 is a β-coronavirus covered with an unsegmented positive-sensing RNA virus (subgenus arbecovirus, orthocoronavirinae subfamily) [4]. A person, after being affected by this virus, will develop a series of symptoms like breathing problems, high fever, cough, chills, muscle pain, headache with sore throat. Symptoms usually takes 2-14 days to appear after being infected [5]. Earlier, it was presumed that, an air temperature

of above 35° C will help in destroying this virus. But, the nature of spread of the COVID-19 in relation to environmental changes have not yet been satisfactorily recognized [6]. The growing population with the increase in demand for food and medical facilities have become the major challenges during this pandemic corona virus outbreak.

Geographical Information System (GIS) is the most important tool to carry out the spatial analysis of the covid19 infected locations. For the society and the researchers, this paper will help the utilities of GIS by spatially mapping the affected geographical areas and further categorising them into high, medium and low risk zones. It will also show a state wise change analysis of COVID19 cases including positive or confirmed cases, active cases, recovered cases and deaths starting from January to the end of April. GIS can be an important tool for information, prevention and treatment of this deadly disease.[7] By analysing spatial information, it can be possible to identify the severity of the disease according to the infected zones along with its intensity of spread which will ultimately help in targeting the hotspots [8]. This paper focuses on the spatially mapping of the affected areas, to show a trend of COVID19, so that timely preventive measures can be taken along with showing the states/regions that doing well in recovering from this infectious disease.

Experimental

This study reviewed research papers prepared on spatial distribution and its impact of the COVID-19 for human resource in India. COVID-19 issues, excepted area, COVID-19 specifically is a cardiovascular disease health conditions and preventive facilities state of India. Spatial analysis approaches apply on monthly cases active, Deaths, Recoveries (COVID-19) and the use GIS obtain a diversity of emerging activates with state wise in India. Research papers using specialization GIS 10.4 Software or its implementing any geospatial analysis techniques [9,10,11]. The data used in this study COVID-19 disease in state wise in India till Jan to 6th May 2020 obtained from the health department of India. In the present research work, spatial distribution pattern of disease, human resources affected by COVID-19. Geospatial techniques are used to forecast the active cases, deaths, recoveries using Inverse Distance Weighted (IDW) and Kriging interpolation techniques. Inverse Distance Weighted IDW is calculates the known information or predicts the value of known area [12]. Its main implications: first, the impact of spatial known value of a location point is extended to the point value which is close to the point specific range. Second, the extent zone of the influence is directly related to the inverse of the range between the points.

Following is the equation used for the spatial analysis [13, 14].

$$Z_p = \frac{\sum_{i=1}^{n}\left(\frac{z_i}{d_i^p}\right)}{\sum_{i=1}^{n}\left(\frac{1}{d_i^p}\right)}$$

Where,

1. Z_p = interpolated value of the unknown point.
2. The weighting function which controls the significance of the control point Z_i is the value observed at the control point "i" which represents the nearest neighborhood of the interpolated point produced and ranges from 20 to 30.
3. "n" is the nearest vicinity of the control points which is usually required to consume time, d_i^p refers to the interpolated point.
4. "p" is a weighting absolute value, where, p = 1 in inverse distance weighting.[15]

Statistical analysis is done on Indian state wish monthly database. Graphs and maps analysis is represented for hospital facilities, health condition and state wise infection growth etc. Impact of COVID-19 on human resources which is one of the powerful resources of economy of every nation.

Study Area

India is a part of the largest continent on the earth i.e., Asia and is situated at the southern part of the continent. The geographic coordinates of India lies between 8°4' N to 37°6' N latitude and 68° 7' E to 97° 25' E longitude. It has a total landmass area of 3287263 square kilometres. It is surrounded by three oceans namely Bay of Bengal in east, Indian Ocean in South and Arabian sea in west while, countries like Myanmar, Nepal, Bhutan, Bangladesh and Pakistan surround India. New Delhi is the capital of India. As per the population count, India is the second highest populated country in the world after China [16,17]. State wise population distribution in India has been listed on table 1 as per the Census, 2011. There are 28 states and 8 union territories. Apart from being the largest democratic country, it has its base on agriculture and several industries such as iron and steel [7].

Table 1: List of state-wise population in India

State-wise population (2011)					
Sr. No	**Name of state/UT**	**Population**	**Sr. No**	**Name of state/UT**	**Population**
1	Andaman and Nicobar	380581	19	Lakshadweep	64473
2	Andhra Pradesh	49386799	20	Madhya Pradesh	72597565
3	Arunachal Pradesh	1382611	21	Maharashtra	112372972
4	Assam	31169272	22	Manipur	2721756
5	Bihar	103804637	23	Meghalaya	2964007
6	Chandigarh	1055450	24	Mizoram	1091014
7	Chhattisgarh	25540196	25	Nagaland	1980602
8	Dadra and Nagar Haveli	585764	26	Odisha	41947358
9	Daman and Diu	585764	27	Pondicherry	1247953
10	Delhi	16787941	28	Punjab	27704236

11	Goa	1457723	29	Rajasthan	68621012
12	Gujarat	60383628	30	Sikkim	607688
13	Haryana	25353081	31	Tamil Nadu	72138958
14	Himachal Pradesh	686402	32	Telangana	35286757
15	Jammu and Kashmir	12548926	33	Tripura	3671032
16	Jharkhand	32966238	34	Uttar Pradesh	199812341
17	Karnataka	61130704	35	Uttarakhand	10116752
18	Kerala	33387677	36	West Bengal	91347736

***Source*:** Census 2011

In the table 1, as per the census 2011, Uttar Pradesh was on the top of highly populated states followed by Maharashtra and Bihar, while states like Sikkim followed by Himachal Pradesh are the less populated states in India.

Results and Discussion

In India, the first corona positive case was detected in Thrissur district of Kerala on 30th January 2020. The patient was a student from Wuhan University, China. As per the medical guidelines, the patient was kept in isolation until his complete recovery as per the Ministry of Health and Family Welfare [18].

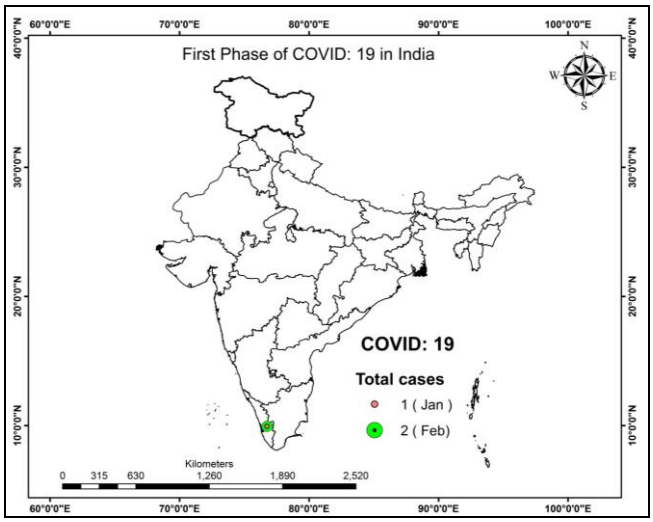

Fig 1: Spatial distribution of first stage of COVID19 cases during January and February 2020

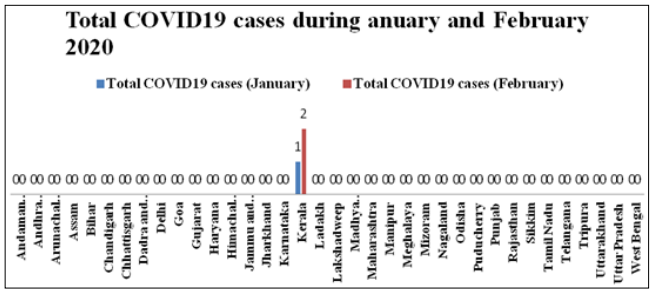

Fig 2: A graphical representation of total COVID19 cases during January and February 2020

In February 2020, two more positive cases were detected in two districts of Kerala. The two coronavirus positive patients were reported to have a travel history from Wuhan, China, which was the virus outbreak epicenter [19,20].

The COVID19 coronavirus infection spread started peaking from the month of March 2020 in different corners of India

With a total number of positive cases of 1394 and 35 death reports. By the end of March, Maharashtra was on top of the highly infected states in India with a count of 254 positive or confirmed cases with 9 death reports. Kerala reported comparatively less positive counts i.e., 231 with 1 death case while Uttar Pradesh was the third highest infected state with 101 confirmed cases and a zero death report.

After evaluating the death reports among the states by the end of March 2020, it was found that, as compared to the total number of positive cases in Gujarat (73), the death rate i.e., 6 was found to be much high than the death rate of Maharashtra i.e., 9 as per its positive cases (254) (Figure 4 & 5). Before the beginning of April month, the status of COVID19 in India was in second stage, which means, the virus is locally transmitted and can spread from an infected person having a travel history from the virus spread state or country can pass on the infection to another person when coming in contact. In this stage, the infected persons can be identified and isolated.

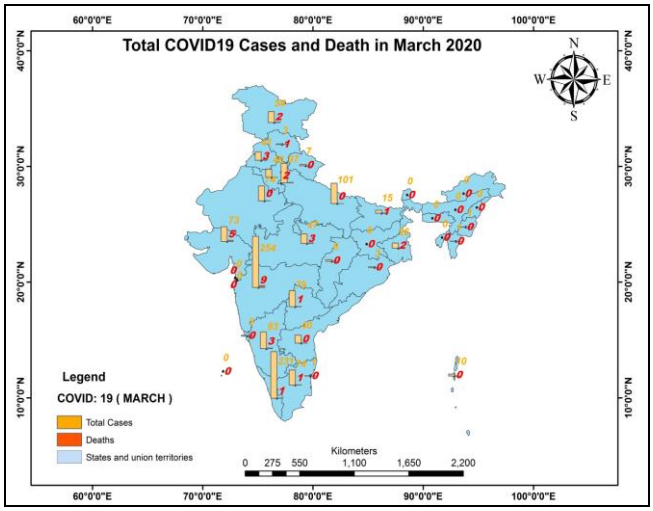

Fig 3: Spatial distribution of total COVID19 cases and deaths during March 2020

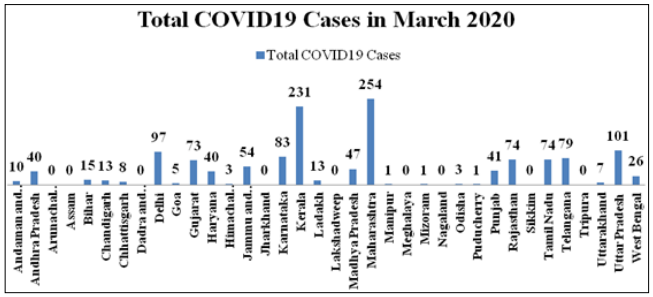

Fig 4: A graphical representation of Total COVID19 cases all over the states in March 2020

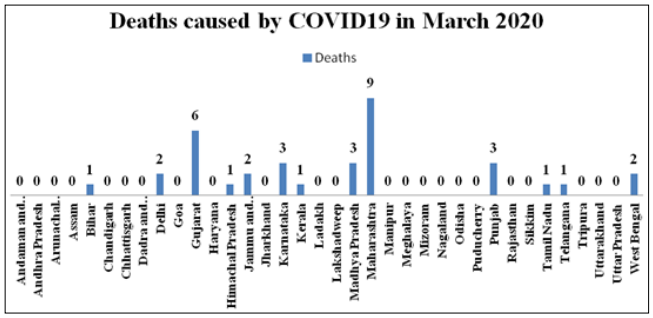

Fig 5: A graphical representation of total deaths reported due to COVID19 in March 2020

After evaluating the death reports among the states by the end of March 2020, it was found that, as compared to the total number of positive cases in Gujarat (73), the death rate i.e., 6 was found to be much high than the death rate of Maharashtra i.e., 9 as per its positive cases (254) (Figure 4 & 5). Before the beginning of April month, the status of COVID19 in India was in second stage, which means, the virus is locally transmitted and can spread from an infected person having a travel history from the virus spread state or country can pass on the infection to another person when coming in contact. In this stage, the infected persons can be identified and isolated.

In April 2020, the virus spread was even more than March, with a significant rise in corona positive cases. As on 30th April 2020, the positive cases toll raised to 31,934 with a death count of 1042. Maharashtra continued to be the most affected state with a huge rise in confirmed Covid19 case i.e., 9661 and 425 deaths followed by Gujarat with 4009 positive cases and 191 deaths and Delhi was found to be the third highest among the affected locations in India with 3342 positive cases and 54 deaths. After evaluating the death reports among the states by the end of April 2020, it was found that, as compared to the total number of positive cases in Madhya Pradesh (2613), the death rate i.e., 127 was found to be much high than the death rate of highly affected locations like Maharashtra, Gujarat and Delhi as per their positive cases. Apart from the states like Rajasthan, Tamil Nadu and Uttar Pradesh which showed comparatively higher corona positive cases than during the month of March, other states showed relatively slower growth of corona positive cases with death reports. State and UTs like Sikkim, Lakshadweep, Dadra-Nagar Haveli and Daman-Diu were found unaffected. The main reason behind the increased COVID19 cases in Maharashtra is high population and closely placed settlements.

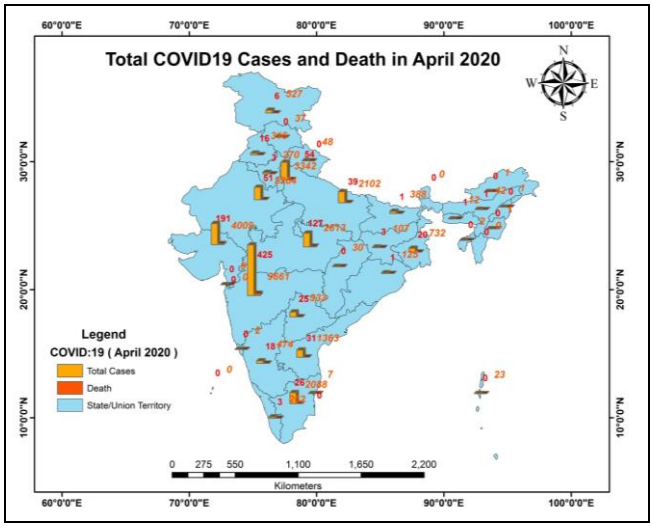

Fig 6: Spatial distribution of total COVID19 cases and deaths during April 2020

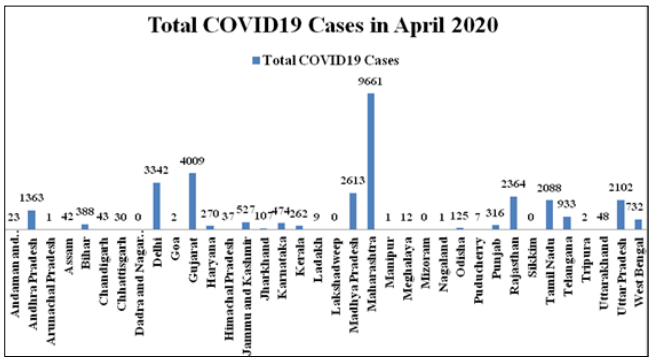

Fig 7: A graphical representation of Total COVID19 cases all over the states in April 2020

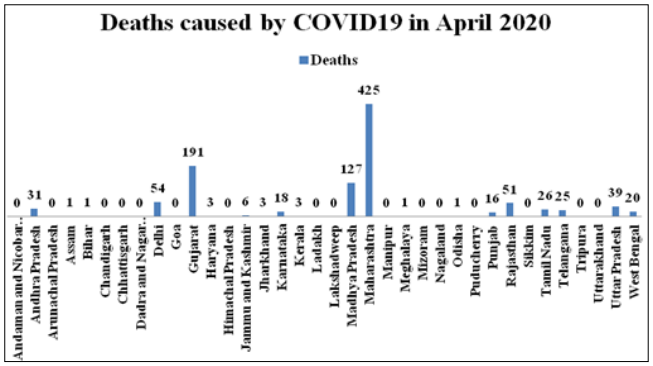

Fig 8: A graphical representation of total deaths reported due to COVID19 in April 2020

In current scenario, the rate of COVID19 cases has reached up to a huge count of 49,391 with active cases up to 33,514, 14,183 recoveries and 1694 death cases. States like Maharashtra, Gujarat and Delhi remained to be the most affected by COVID19 as per the Ministry of Health and Family Welfare (Table 2). For spatial distribution of the current status of COVID19 in India, interpolation using Inverse Distance Weighted (IDW) method was used to show the magnitude of the infection spread (Figure 9).

Table 2: Current status of COVID19 in different states of India

Confirmed cases, deaths, and recoveries by state and union territory					
COVID-19 pandemic in India by state and union territory					
S. No.	State/Union Territory	Total cases	Deaths	Recoveries	Active cases
1	Andaman and Nicobar Islands	33	0	32	1
2	Andhra Pradesh	1717	36	589	1092
3	Arunachal Pradesh	1	0	1	0
4	Assam	43	1	32	10
5	Bihar	536	4	142	390
6	Chandigarh	111	1	21	89
7	Chhattisgarh	59	0	36	23
8	Dadra and Nagar Haveli and Daman and Diu	0	0	0	0
9	Delhi	5104	64	1468	3572
10	Goa	7	0	7	0
11	Gujarat	6245	368	1381	4496
12	Haryana	548	6	256	286
13	Himachal Pradesh	42	2	38	2
14	Jammu and Kashmir	741	8	320	413
15	Jharkhand	125	3	33	89
16	Karnataka	671	29	331	311
17	Kerala	502	4	462	36
18	Ladakh	41	0	17	24
19	Lakshadweep	0	0	0	0
20	Madhya Pradesh	3049	176	1000	1873
21	Maharashtra	15525	617	2819	12089
22	Manipur	2	0	2	0
23	Meghalaya	12	1	10	1
24	Mizoram	1	0	0	1
25	Nagaland	0	0	0	0
26	Odisha	175	1	60	114
27	Puducherry	9	0	6	3
28	Punjab	1451	25	133	1293
29	Rajasthan	3158	89	1525	1544
30	Sikkim	0	0	0	0
31	Tamil Nadu	4058	33	1485	2540
32	Telangana	1096	29	585	482
33	Tripura	43	0	2	41
34	Uttar Pradesh	2880	56	987	1837
35	Uttarakhand	61	1	39	21
36	West Bengal	1344	140	364	840
Total		49391*	1694	14183	33514

***Source*:** Ministry of Health and Family Welfare (data as on 6th May 2020)

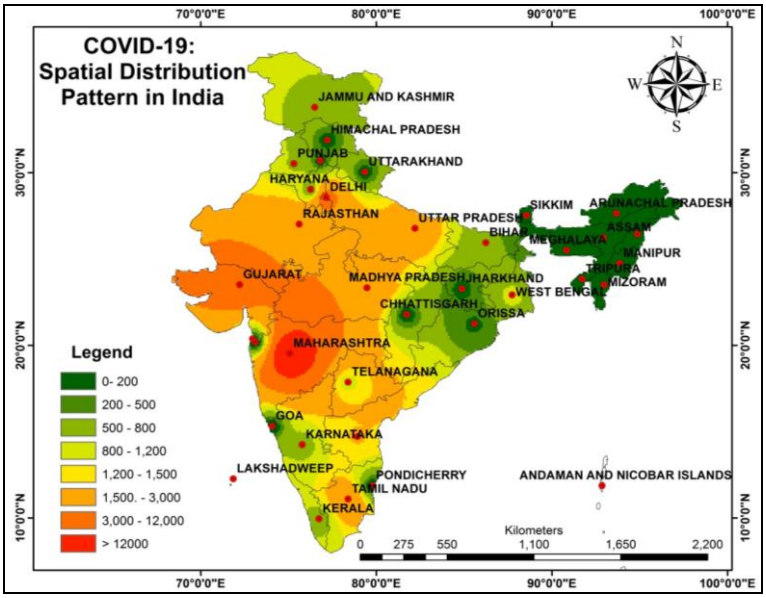

Fig 9: Current spatial distribution pattern of COVID19 in India using IDW method

The descriptive statistical analysis shows that, there is an average of 1372 total COVID19 cases, 393 recoveries, 47 deaths and 931 active cases per day as per the present scenario (Table 3). This rate of growth in total COVIID19 cases is a threat to the citizens of India as well as its economy.

Table 3: Descriptive statistics of COVID-19 pandemic in India by state and union territory.

Descriptive statistics	Total cases	Deaths	Recoveries	Active cases
Mean	1371.944444	47.055556	393.9722222	930.9166667
Standard Error	481.6650287	20.058879	106.4902372	365.1205984
Median	118	1.5	38.5	65
Mode	0	0	0	0
Standard Deviation	2889.990172	120.35328	638.941423	2190.723591
Sample Variance	8352043.197	14484.911	408246.1421	4799269.85
Kurtosis	16.67175065	15.572913	4.986719257	19.89559724
Skewness	3.742336299	3.7984459	2.149714003	4.149804814
Range	15525	617	2819	12089
Minimum	0	0	0	0
Maximum	15525	617	2819	12089
Sum	49390	1694	14183	33513
Count	36	36	36	36

Doctors are playing a crucial role during the COVID19 pandemic by treating the infected patients. High recovery rate and a low death rate in Kerala and Delhi indicates better medical facilities with a suitable patient and doctor ratio. Maharashtra being the highly affected has the highest death rate with comparably lowest recovery rate due to more COVID19 affected people than the available doctors and hospitals. Medical facilities at other states like Tamil Nadu and Rajasthan are performing well by providing a relatively high recovery rate and low death rate as per their total active cases.

Apart from the human health being affected and the lockdown due to the COVID19 spread, India's economy is greatly affected as all the finance building sectors are closed due to the national emergency.

Preventive measure to save human resources from COVID19

Immunity-Best weapon to fight COVID 19:

In wake of the recent pandemic COVID 19 and its devastating effects, much thought has gone into trying to seek a respite from the infection. Deliberations on the topic have led to the truth that, the best weapon to fight this deadly infection is one's immunity system. Viruses are not killed by antibiotics, like bacteria as they have a different structure and reproductive system. By boosting the immunity system, such infections can be prevented or cured. Pyrogens are chemicals which raise the body temperature and thus cause impairment of reactions, in turn hampering the metabolism of the organism. Our diet is the strongest source to sharpen this weapon of ours.

Vitamin C enhances the immunity factor of a human body which ultimately helps to fight any kind of illness [21]. Foods rich in Vitamin C, best fortify our bodies against infections. These include lemon (*Citrus limon*), orange (*Citrus sinensis*), amla (*Emblica officinalis*), red and green pepper (*Capsicum annum*) and so on. Vitamin C has antioxidative properties and helps protect immune system against oxidative stress released during infections. Also, accelerates antibody response in the body and helps in treating acute upper respiratory tract infections. Ginger (*Zingiber officinale*), possess strong anti-microbial properties. Active ingredients like terpenes and oleoresin are present in ginger oil. These substances are also helpful in neutralizing the harmful effects of free radicals generated during oxidative stress caused due to infections. Allicin, one of the active

principles of freshly crushed garlic (*Allium sativum*) homogenates possess strong anti-microbial properties arising due to its ability to obstruct the metabolism of the microorganism. Several studies have reported broad spectrum antimicrobial activity of curcumin (a principal curcuminoid of turmeric) in combination with aloe-vera. Momordicin derived from bitter gourd (*Momordica charantia*) has been established as a potential fighter for the treatment of cough and respiratory diseases.

Safety measure of Dairy and food items in Covid-19:

Proper nutrition is something really essential in Covid-19. People having a well-balanced diet tend stay healthier with stronger immune systems and lower risk of persistent illnesses and infectious diseases. Therefore, it is recommended to eat a variety of dairy and food items every day to get required vitamins, protein, minerals, dietary fibre and antioxidants that our body needs. It is advised to eat fruits and vegetables each day, as it contains essential immunity providing minerals. Drinking water is an essential part; therefore, drinking at least 8-12 cups of water is necessary. Drinking warm water during COVID19 situation is essential too, as it kills harmful cold and cough causing bacteria up to some extent. Foods containing fat, sugar and salt should be consumed less to considerably lower the risk of overweight, obesity, heart disease, stroke, diabetes and certain types of cancer. Outside foods should be avoided as it may contain infections from the seller's hand, while it will be difficult to know whether the seller's hands are clean and the place is disinfected [22,23].

No confirmation has been found about the spread of COVID19 virus to humans through foods obtained from animal origin. Preventing contamination in the food chain will help to reduce food borne illness and lessen the probability of the emergence of novel diseases such as COVID-19. Legally dairy and food products can be safe for consumption if safe food handling and preparation practices are followed. Milk and dairy products such as ghee, cheese, low fat dairy product, fermented dairy products etc. are safe to consume in COVID-19. Ghee contains cancer-fighting conjugated linolenic acid (CLA) and has anti-inflammatory properties to prevent the health while, proper nutrition and hydration improve health and immunity. People living with constant illnesses that have suspected or confirmed COVID-19 may need support to their mental health and diet to make sure they keep in good health and recover faster in case infected. Food can become contaminated with microorganisms that can cause human illness from multiple sources along with the entire food chain, starting from infections residing in animals up to the point of consumption. Preventing such contamination will reduce food borne illness and decrease the possibility of novel pathogens rising in the food chain. Currently, there is no such facts has been found that the COVID19 corona virus pandemic is transmitted by domestic food-producing animals, such as cow, buffalo, goats etc [24].

Conclusions

This research work was carried out using geospatial technologies to illustrate the spatial distribution of COVID19 infection all over India. The main objective was to evaluate the change in the rate of the COVID19 cases across different states by performing a trend analysis from January to May 2020. By the end of April, it was found that, Maharashtra was the highly affected state by COVID19 infection followed by Gujarat and Delhi. Results of the IDW method interpolation revealed that, the disease is spreading in a rapid pace as compared to the initial months. An attempt has been made to help the organisations that are associated with the COVID19 work, so that appropriate planning, preventive and curative steps can be taken. Apart from that, the essential nutrition and foods responsible for development of immunity that can tackle such infections has been mentioned. As per the spatial-temporal change distribution of COVID19 analysis, it will be helpful to take necessary steps by the government to supervise and forecast the vast of further spread of the COVID19 infection at the most affected regions and the adjacent regions to it as well as to prevent the least affected regions.

Acknowledgements

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