



P-ISSN: 2706-7483  
E-ISSN: 2706-7491  
IJGGE 2022; 4(1): 123-131  
Received: 22-12-2021  
Accepted: 17-02-2022

**V Saravanabavan**  
Assistant Professor,  
Department of Geography,  
Madurai Kamaraj University,  
Madurai, Tamil Nadu, India

**C Vinothini**  
Research Assistant, RUSA-II,  
Department of Geography,  
Madurai Kamaraj University,  
Madurai, Tamil Nadu, India

**D Balaji**  
Gust Faculty, Department of  
Geography, Bharathidasan  
University, Tiruchirappalli,  
Tamil Nadu, India

**Alok Manna**  
PG Project Fellow,  
Department of Geography,  
Madurai Kamaraj University,  
Madurai, Tamil Nadu, India

**Arya Mohan**  
PG Project Fellow,  
Department of Geography,  
Madurai Kamaraj University,  
Madurai, Tamil Nadu, India

**Athira Rajesh**  
PG Project Fellow,  
Department of Geography,  
Madurai Kamaraj University,  
Madurai, Tamil Nadu, India

**Corresponding Author:**  
**C Vinothini**  
Research Assistant, RUSA-II,  
Department of Geography,  
Madurai Kamaraj University,  
Madurai, Tamilnadu, India

## A geo-spatial approach on COVID-19 mortality in Tamil Nadu

**V Saravanabavan, C Vinothini, D Balaji, Alok Manna, Arya Mohan and Athira Rajesh**

### Abstract

COVID-19 is an infectious respiratory disease which occurred first in Wuhan, China and evolved rapidly around the globe. The disease is transmitted among humans either through direct contact or via droplets from sneeze or cough. The study area Tamil Nadu is the southern state of India. It lies between 8° 05' and 13° 34' North Latitudes and 76° 14' and 80° 21' East Longitudes. The state covers an area of about 130,058 sq km and is the eleventh largest state in India. The main objective of the study is to analyze the spatial pattern of variation of COVID-19 noticed between different state wise investigations from March 2020 to March 2021. To identify the major regions of disease and to observe the related conditions. To derive a conceptual framework towards strengthening the foundation for integrated health care of the state. The analysis of COVID-19 in Tamil Nadu state is mainly based on secondary data. For the purpose of this study statistical techniques of Z score analysis and map Interpretation are used. It includes mapping of the disease using the GIS software of Arc GIS. The findings indicate that Chennai, Chengalpattu, Tiruchirappalli districts show extreme mortality cases in Tamil Nadu.

**Keywords:** COVID-19, Mortality rate, spatial variation, Z score, GIS

### Introduction

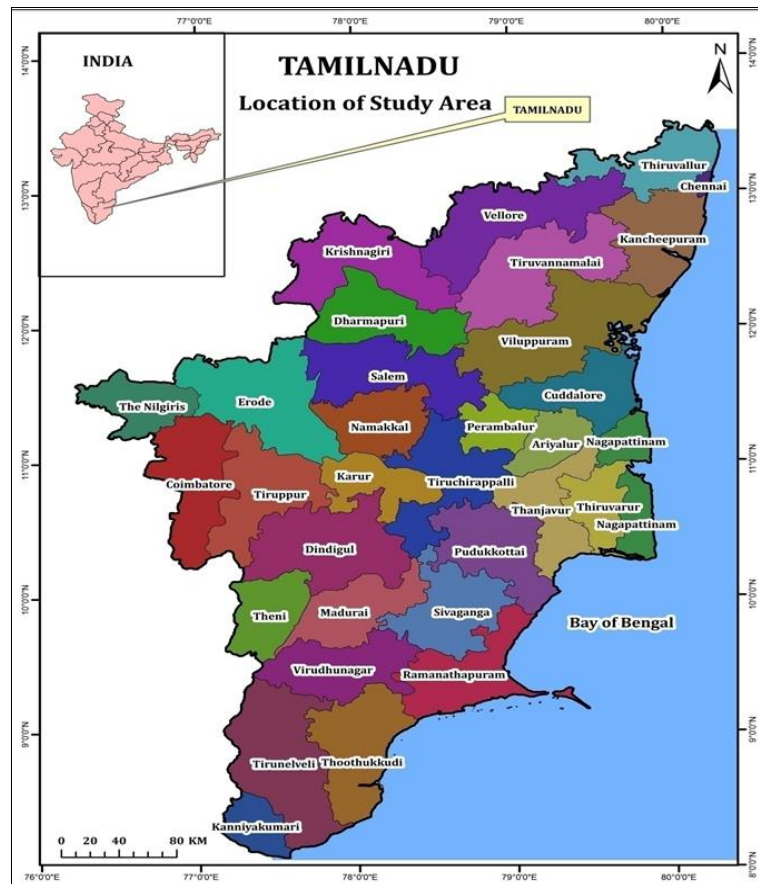
COVID-19 is an infectious respiratory disease which occurred first in Wuhan, China and evolved rapidly around the globe. The causative pathogen is a novel corona virus called SARS-CoV [1]. The disease is transmitted among humans either through direct contact or via droplets from sneeze or cough. Symptoms of COVID-19 are variable, but often include fever, cough, fatigue, breathing difficulties, and loss of smell and taste [2, 3]. Symptoms begin one to fourteen days after exposure to the virus. Of those people who develop noticeable symptoms, most (81%) develop mild to moderate symptoms (up to mild pneumonia), while 14% develop severe symptoms (dyspnoea, hypoxia, or more than 50% lung involvement on imaging), and 5% suffer critical symptoms (respiratory failure, shock, or multiorgan dysfunction) [4]. At least a third of the people who are infected with the virus remain asymptomatic and do not develop noticeable symptoms at any point in time, but they still can spread the disease. [5] The virus that causes COVID-19 spreads mainly when an infected person is in close contact with another person, Small droplets and aerosols containing the virus can spread from an infected person's nose and mouth as they breathe, cough, sneeze, sing, or speak. Other people are infected if the virus gets into their mouth, nose or eyes. The virus may also spread via contaminated surfaces, although this is not thought to be the main route of transmission [6, 7].

Medical geography is a multidimensional body of knowledge and at the same time a multifaceted approach is geared towards understanding the spatial aspects of health problems. [8, 9, 10, 11] medical geography is an area of geographical research that incorporates geographical techniques into the study of health around the world and studies the impact of climate and location on an individual's health as well as the distribution of health services [12, 13, 14, 15]. Diseases are not uniformly distributed over the surface of the earth [16, 17, 18]. There are different patterns of distribution of various diseases [19, 20, 21]. When a systematic study is made about the spatial distribution of disease in which the diseased person lives in relation to the environment thus comes a new field that is medical geography [22, 23, 24, 25].

**Study Area**

Tamil Nadu is situated on the eastern side of the Indian sub-continent. This is a land of mountains, rivers and coastal plains. Tamil Nadu is the southern state of India. It lies

between 8° 05' and 13° 34' North Latitudes and 76° 14' and 80° 21' East Longitudes. (Fig 1) The state covers an area of about 130,058 sq km and is the eleventh largest state in India.



**Fig 1:** Location of Study Area

**Methodology**

The analysis of COVID-19 in Tamil Nadu state is mainly based on secondary data. ‘Z’ scores help us to convert scores from different data sets into scores that can be accurately fitted with each other. Standard scores also known as ‘Z’ scores, Z values, standard variables and normal score and numerical figures that indicate the number of standard deviation, above or below, that a particular observation has with relation to a given mean value. The ‘Z’ score type is a pure number which is characterized by a complete lack of association with any sort of physical dimension. The most obvious description of Medical Geography is the spatial distribution of the morbidity, mortality from various causes [26, 27, 28].

A ‘Z’ score is a statistical measurement of a score’s relationship to the mean in a group scores. A ‘Z’ scores can also be positive or negative indicating whether it is above or below the mean and standard deviation. [29, 30] ‘Z’ score can also be explained as in addition of showing a score’s relationship to the mean. The ‘Z’ score shows statistical data set. One real life application of ‘Z’ score is an usability testing’s score is arrived at by calculating the difference so derived is divided by the standard deviation of the population. The Z score formula is as follows.

$$Z = \frac{X-U}{Q}$$

According to Z score analysis the region may be classified into 4 categories such as extreme (representing values of >0.20) High(0.01-0.) moderate(-0.20-0.00), and low(<-

0.20). On the basis of the above classifications district wise disease distribution is undertaken with the help of Zscore analysis.

The Zscore distribution pattern of COVID-19 prevalence of death case for the month of March 2020 is shown in (Table 1). The disease rate is distributed all over the districts of Tamil Nadu. Standard deviation is a number used to tell how measurements for a group are spread out from the average (mean or expected value). A low standard deviation means that most of the numbers are close to the average, while a high standard deviation means that the numbers are more spread out [31, 32]. (Table 2)

**Spatial and temporal variation of COVID-19 prevalence of death case in Tamilnadu March 2020 March 2021**

The initial death case in this regard in the very beginning of March 2020 was only one case. This was the primary wave of the disease which was progressing in the upcoming months.

**Spatial Variation of COVID-19 prevalence of Death case In Tamil Nadu May 2020**

As per the details enlisted from data shown below, it is interpreted that the death rate of Tamil Nadu varies in the statistical survey. [33, 34, 35] Each month the z score value is different. For example when we closely analyse the data in the month of May the areas such as Shivagangai, Tiruvarur, Thanjavur, Pudukottai, Perambalur, Ariyalur, Nagapattinam, Thoothukudi, Ramanathapuram, Virudhnagar, Thenkasi, Krishnagiri, Tirupattur, Dharmapuri, Salem, Kallakurichi,

Tiruvanamalai, Cuddalore, Karur, Nammakal, Nilgiris, Theni, Villupuram show a very low degree of cases of death. The inhabitants of these areas might have followed strict protocols of the disease. The survey shows that the

affected cases of the areas Kanayakumari, Dindigul, Erode Tirunellveli, Coimbatore, Tiruppur, Madurai is about moderate.

**Table 1:** Spatio-Temporal Variation of COVID-19 Prevalence of Death Case in Tamilnadu: ‘Z’ Score Analysis

S. No	Districts	March 2020	May 2020	July 2020	September 2020	November 2020	January 2021	March 2021	Total cases
		‘Z’ Score Value							
1	Ariyalur	-0.164	-0.221	-0.288	-0.423	-0.433	-0.430	-0.431	-0.411
2	Chengalpattu	-0.164	0.299	0.411	0.575	0.639	0.656	0.659	0.607
3	Chennai	-0.164	5.877	5.820	5.718	5.694	5.692	5.692	5.724
4	Coimbatore	-0.164	-0.174	-0.152	0.346	0.478	0.509	0.513	0.389
5	Cuddalore	-0.164	-0.174	-0.218	-0.059	-0.067	-0.074	-0.074	-0.088
6	Dharmapuri	-0.164	-0.221	-0.297	-0.448	-0.429	-0.423	-0.422	-0.412
7	Dindigul	-0.164	-0.174	-0.163	-0.186	-0.197	-0.204	-0.205	-0.195
8	Erode	-0.164	-0.174	-0.282	-0.326	-0.286	-0.278	-0.280	-0.289
9	Kallakurichi	-0.164	-0.221	-0.242	-0.312	-0.339	-0.341	-0.342	-0.323
10	Kancheepuram	-0.164	-0.126	0.014	0.116	0.172	0.159	0.162	0.135
11	Kanyakumari	-0.164	-0.174	-0.195	-0.068	-0.104	-0.116	-0.113	-0.114
12	Karur	-0.164	-0.221	-0.282	-0.421	-0.434	-0.429	-0.429	-0.410
13	Krishnagiri	-0.164	-0.221	-0.268	-0.376	-0.330	-0.328	-0.327	-0.329
14	Madurai	5.918	-0.079	0.379	0.255	0.197	0.186	0.185	0.223
15	Nagapattinam	-0.164	-0.221	-0.285	-0.339	-0.310	-0.305	-0.305	-0.310
16	Namakkal	-0.164	-0.174	-0.291	-0.359	-0.346	-0.337	-0.338	-0.337
17	Nilgiris	-0.164	-0.221	-0.303	-0.450	-0.442	-0.433	-0.432	-0.421
18	Perambalur	-0.164	-0.221	-0.300	-0.459	-0.476	-0.473	-0.473	-0.449
19	Pudukottai	-0.164	-0.221	-0.236	-0.229	-0.262	-0.269	-0.269	-0.256
20	Ramanathapuram	-0.164	-0.174	-0.123	-0.268	-0.299	-0.297	-0.299	-0.271
21	Ranipet	-0.164	-0.221	-0.216	-0.196	-0.222	-0.222	-0.221	-0.217
22	Salem	-0.164	-0.221	-0.218	0.133	0.197	0.200	0.194	0.132
23	Sivagangai	-0.164	-0.221	-0.184	-0.264	-0.307	-0.314	-0.315	-0.288
24	Tenkasi	-0.164	-0.221	-0.253	-0.231	-0.260	-0.266	-0.266	-0.257
25	Thanjavur	-0.164	-0.221	-0.227	-0.154	-0.141	-0.131	-0.130	-0.150
26	Theni	-0.164	-0.126	-0.129	-0.155	-0.193	-0.195	-0.194	-0.179
27	Thirupathur	-0.164	0.221	-0.262	-0.316	-0.312	-0.314	-0.315	-0.308
28	Thiruvallur	-0.164	0.299	0.385	0.557	0.544	0.539	0.538	0.524
29	Thiruvannamalai	-0.164	-0.126	-0.129	-0.049	-0.067	-0.077	-0.079	-0.077
30	Thiruvarur	-0.164	-0.221	-0.282	-0.359	-0.342	-0.340	-0.338	-0.336
31	Thoothukudi	-0.164	-0.126	-0.172	-0.262	-0.291	-0.291	-0.290	-0.270
32	Tirunelveli	-0.164	-0.174	-0.198	-0.113	-0.172	-0.183	-0.184	-0.170
33	Tiruppur	-0.164	-0.221	-0.279	-0.233	-0.175	-0.171	-0.169	-0.196
34	Trichy	-0.164	-0.221	-0.134	-0.217	-0.233	-0.232	-0.229	-0.217
35	Vellore	-0.164	-0.174	-0.131	-0.030	0.023	0.021	0.020	-0.008
36	Villupuram	-0.164	-0.126	-0.207	-0.308	-0.333	-0.335	-0.335	-0.313
37	Virudhunagar	-0.164	-0.221	-0.062	-0.090	-0.144	-0.155	-0.157	-0.131

**Table 2:** Descriptive Statistics Value of COVID-19 on March 2020 to March 2021

	N	Minimum	Maximum	Mean	Std. Deviation
VAR00001	37	.00	1.00	.0270	.16440
VAR00002	37	.00	129.00	4.6757	21.15558
VAR00003	37	2.00	2113.00	106.3243	344.79527
VAR00004	37	20.00	3210.00	257.2703	516.42912
VAR00005	37	21.00	3850.00	316.4865	620.52409
VAR00006	37	21.00	4102.00	333.8919	661.98375
VAR00007	37	21.00	4138.00	336.7027	667.86342
VAR00008	37	86.00	17542.00	1355.3784	2827.80691
Valid N (listwise)	37				

**Table 3:** District wise Mortality in the month of May 2020

Z-Score Interval	Ranking	Districts
<-0.20	Low	Sivagangai, Tiruvarur, Thanjavur, Pudukottai, Perambalur, Ariyalur, Nagapattinam, Thoothukudi, Ramanathapuram, Virudhanagr, Thenkasi, Krishnagiri, Tirupattur, Dharamapuri, Salem, Kallakurichi, Tiruvannamalai, Cuddalore, Karur, Nammakal, Nilgiris, Theni, Villupuram
-0.20-0.00	Moderate	Kanyakumari, Dindigul, Erode, Tirunelveli, Coimbatore, Tiruppur, Madurai
0.01-0.20	High	Tiruvallur, Ranipet, Vellore, Kancheepuram
>0.20	Extreme	Chengalpattu, Chennai, Tiruchirapalli

In the meantime when the survey progresses, in cities like Ranipet, Tiruvallur, Vellore, Kancheepuram the prevalence of death cases are very high. (Fig 2) It might be because of social indulging of people in these areas. Further the study shows clearly that the inhabitants of Chennai, Chengalpettu, Tiruchirapally in July (Fig 3) have extreme cases since many of these are metro cities and the people might not have followed the protocols. (Table 3)

**Spatial Variation of COVID-19 Prevalence of Death case In Tamil Nadu -September 2020**

The spatial variation of COVID-19 death cases in Tamil Nadu shows a varied intensity in the month of September. (Fig 4) The area like Tiruvarur, Thanjavur, Pudukottai, Perambalur, Ariyalur, Nagapattinam, Thoothukudi, Ramanathpuram, Virudhnagar, Thenkasi, Krishnagiri, Tirupattur, Dharmapuri, Salem, Kallakurichi, Tiruvanamalai, Cuddalore, Karur, Nammakal, Nilgiris, Villupuram were not much affected but the areas such as Kanyakumari, Tirunellveli, Virudhnagar, Teni, Dindigul, Salem, Cuddalore, Nilgiris, Vellore, Tiruvallur show moderate death cases. (Table 4)

**Table 4:** District wise Mortality in the month of September 2020

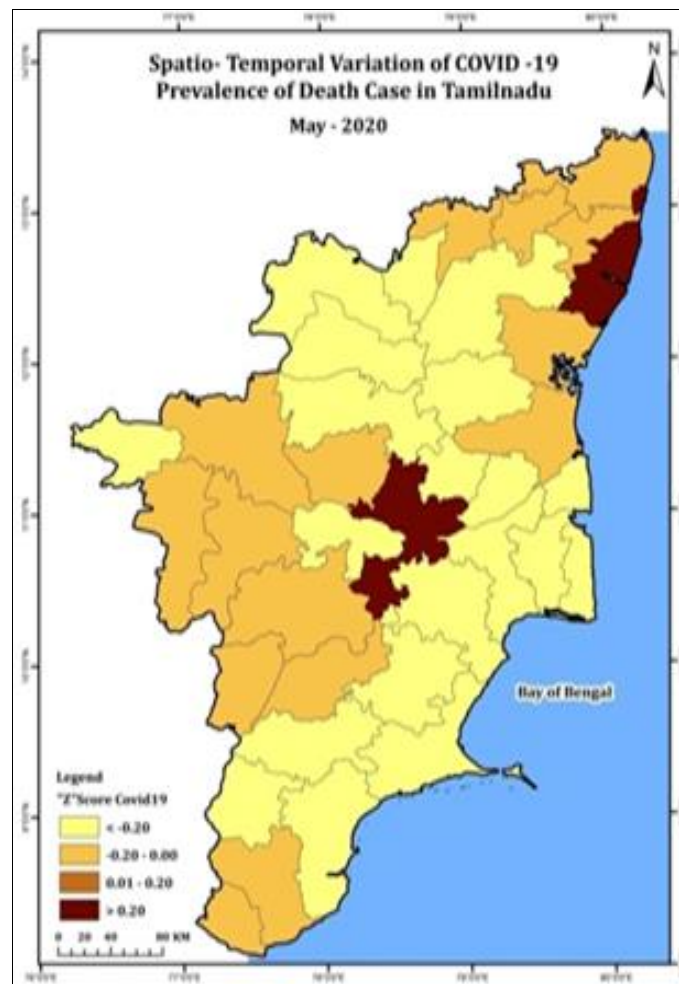
Z-Score Interval	Ranking	Districts
<-0.20	Low	Tiruvarur, Thanjavur, Pudukottai, Perambalur, Ariyalur, Nagapattinam, Thoothukudi, Ramanathpuram, Virudhanagr, Thenkasi, Krishnagiri, Tirupattur Dharamapuri, Kallakurichi, Tiruvanamallai, Cuddalore, Karur, Nammakal, Nilgiris, Villupuram
-0.20-0.00	Moderate	Kanyakumari, Tirunellveli, Virudhnagar, Teni, Dindigul, Salem, Cuddalore, The Nilgiris, Vellore, Tiruvallur,
0.01-0.20	High	Sivagangai, Kancheepuram
>0.20	Extreme	Madurai, Tiruchirapally, Chennai, Chengalpettu

The districts of Sivagangai and Kancheepuram had high intensity death cases. At the same time Madurai, Chennai, Tiruchirapally, Chengalpettu show the extreme numbers in this respect.

**Spatial Variation of COVID-19 Prevalence of Death case In Tamil Nadu -November 2020**

As the survey proceeds to the month of November low

death cases were reported in Shivagangai, Tiruvarur, Thanjavur, Pudukottai, Perambalur, Ariyalur, Nagapattinam, Thoothu kudi, Ramanathpuram, Virudhnagar, Thenkasi, Krishnagiri, Tirupattur, Dharmapuri, Salem, Kallakurichi, Tiruvanamalai, Karur, Nammakal, Nilgiris, Villupuram, Moderate cases were in Kanya kumari, Tirunellveli, Virudhnagar, Teni, Dindigul, Cuddalore, Tiruvanamalai, Tiruvallur. (Table 5).



**Fig 2:** Spatial distribution of COVID-19 in Tamilnadu

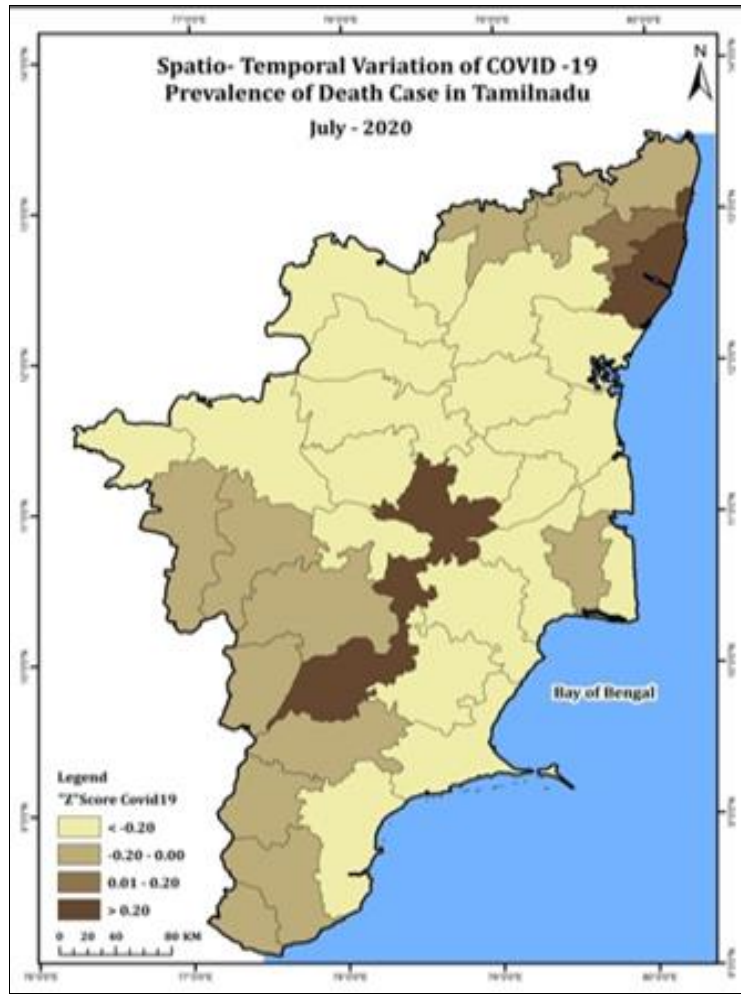


Fig 3: Spatial distribution of COVID-19 in Tamilnadu

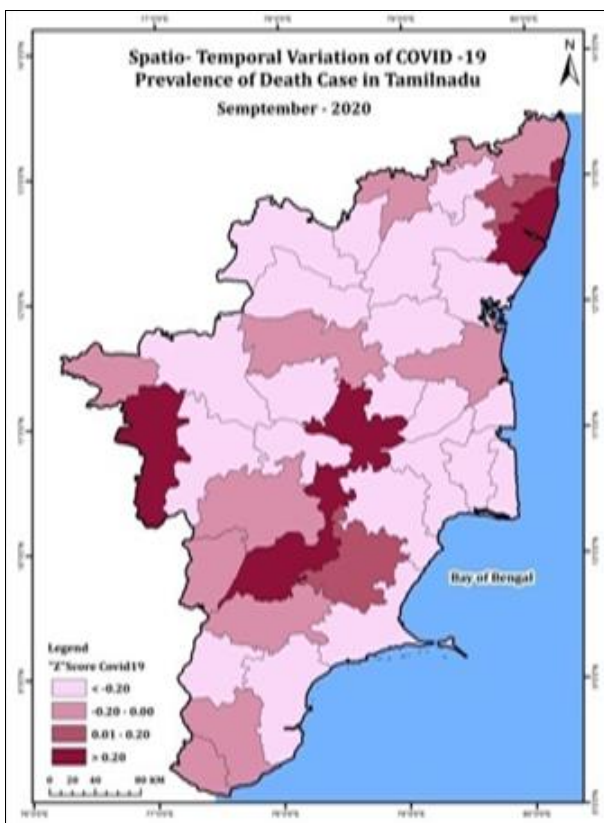


Fig 4: Spatial distribution of COVID-19 in Tamil Nadu

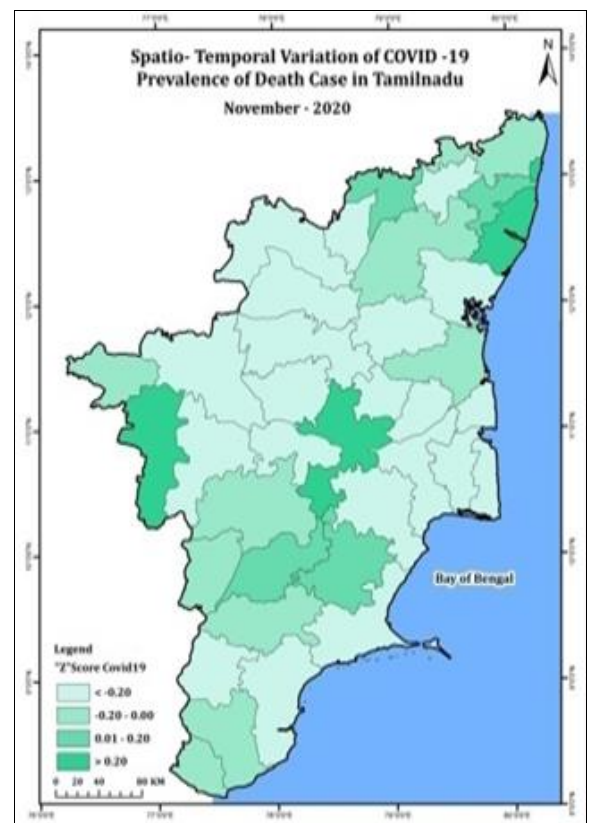


Fig 5: Spatial distribution of CODID-19 in Tamil Nadu

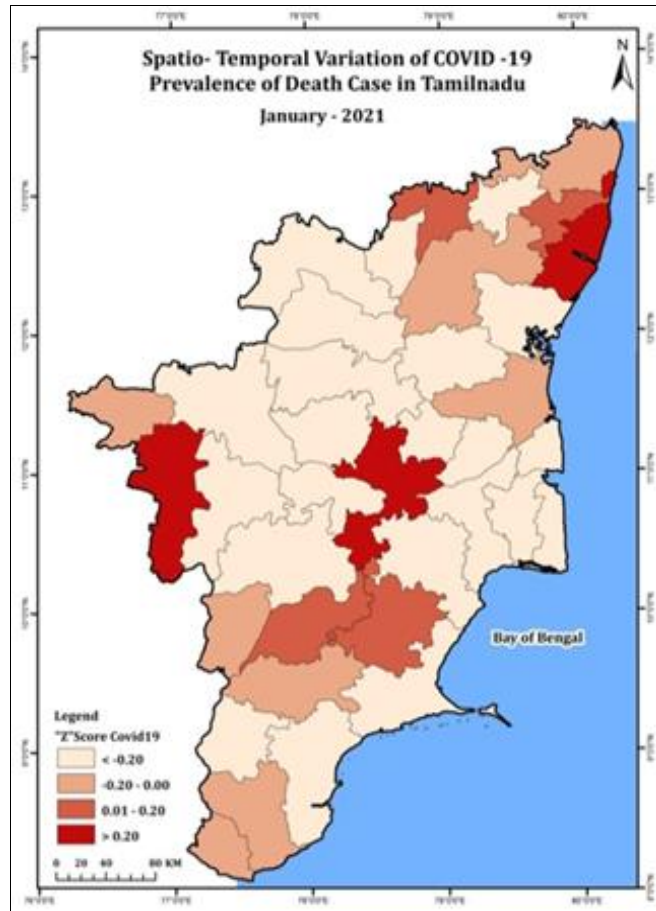


Fig 6: Spatial distribution of COVID-19 in Tamil Nadu

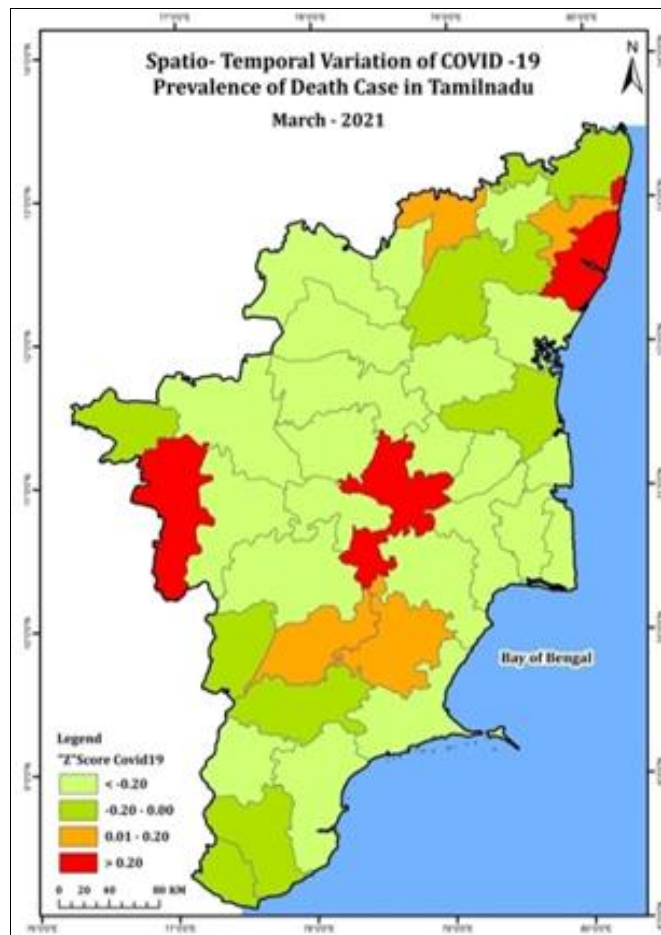


Fig 7: Spatial distribution of COID-19 in Tamil Nadu

**Table: 5** District wise Mortality in the month of November 2020

Z-Score Interval	Ranking	Districts
<-0.20	Low	Sivagangai, Tiruvarur, Thanjavur, Pudukottai, Perambalur, Ariyalur, Nagapattinam, Thoothukudi, Ramanathapuram, Virudhanagr, Thenkasi, Krishnagiri, Tirupattur, Dharamapuri, Salem, Kallakurichi, Tiruvanamallai, Karur, Nammakal, Nilgiris, Villupuram
-0.20-0.00	Moderate	Kanyakumari, Tirunellvelli, Virudhnagar, Teni, Dindigul, Cuddalore, Tiruvanamallai, Tiruvallur
0.01-0.20	High	Madurai, Sivagangai, The Nilgiris, Kancheerapuram, Vellore
>0.20	Extreme	Tiruchirapally, Coimbatore, Chennai, Chengalpettu

Due to the densely packed areas of population there were high number of cases in the cities of Madurai, Sivagangai, Nilgiris, Kancheepuram, Vellore and extremely high in Chennai, Chengalpettu, Coimbatore, and Tiruchirapally. As people failed follow to COVID-19 protocols and social distancing, the death rates were very high.

**Spatial Variation of COVID-19 Prevalence of Death case In Tamil Nadu -January 2021**

In the month of January the cases were very low in Tiruvarur, Thanjavur, Pudukottai, Perambalur, Ariyalur,

Nagapattinam, Thoothukudi, Ramanatha puram, Virudhnagar, Thenkasi, Krishnagiri, Tirupattur, Dharamapuri, Salem, Kallakurichi, Tiruvanamallai, Cuddalore, Karur, Nam makal, Nilgiris, Theni, Villupuram and moderate in the areas of Kanyakumari, Tirunellvelli, Virudhnagar, Theni, Nilgiris, Cuddalore, Tiruvanamallai, Tiruvallur where as it is reported high in Madurai, Sivagangai, Kancheepuram, Vellore and extreme in Tiruchirapally, Coimbatore, Chennai, Chengalpettu. (Table 6) (Fig 6)

**Table 6:** District wise Mortality in the month of January 2021

Z-Score Interval	Ranking	Districts
<-0.20	Low	Tiruvarur, Thanjavur, Pudukottai, Perambalur, Ariyalur, Nagapattinam, Thoothukudi, Ramanathapuram, Virudhanagr, Thenkasi, Krishnagiri, Tirupattur, Dharamapuri, Salem, Kallakurichi, Tiruvanamallai, Cuddalore, Karur, Nammakal, Nilgiris, Theni, Villupuram
-0.20-0.00	Moderate	Kanyakumari, Tirunellvelli, Virudhnagar, Teni, The Nilgiris, Cuddalore, Tiruvanamallai, Tiruvallur
0.01-0.20	High	Madurai, Sivagangai, Kancheerapuram, Vellore
>0.20	Extreme	Tiruchirapally, Coimbatore, Chennai, Chengalpettu

**Spatial Variation of COVID-19 Prevalence of Death case In Tamil Nadu -March 2021**

When the study proceeds further to the month of March the cases were very low in areas like Tiruvarur, Thanjavur, Pudukottai, Perambalur, Ariyalur, Nagapattinam, Thoothukudi, Ramana thpuram, Virudhnagar, Thenkasi, Krishnagiri, Tirupattur, Dharamapuri, Salem, Kallakurichi, Tiruva namalai, Karur, Nammakal, Nilgiris, Villupuram and

moderate in the cities of Kanyakumari, Tiru nellvelli, Virudhnagar, Theni, Nilgiris, Cuddalore, Tiruvanamallai, Tiruvallur. (Fig 7) But further, the sur vey makes us to conclude that there were high cases in areas like Madurai, Sivagangai, Kanchee puram, Vellore and extreme in Tiruchirapally, Coimbatore, Chennai, Chengalpettu. (Table 7)

**Table 7:** District wise Mortality in the month of March 2021

Z-Score Interval	Ranking	Districts
<-0.20	Low	Tiruvarur, Thanjavur, Pudukottai, Perambalur, Ariyalur, Nagapattinam, Thoothukudi, Ramanathapuram, Virudhanagr, Thenkasi, Krishnagiri, Tirupattur, Dharamapuri, Salem, Kallakurichi, Tiruvanamallai, Karur, Nammakal, Nilgiris, Villupuram
-0.20-0.00	Moderate	Kanyakumari, Tirunellvelli, Virudhnagar, Teni, The Nilgiris, Cuddalore, Tiruvanamallai, Tiruvallur
0.01-0.20	High	Madurai, Sivagangai, Kancheerapuram, Vellore
>0.20	Extreme	Tiruchirapally, Coimbatore, Chennai, Chengalpettu

**Temporal variation of COVID-19 prevalence of deathcase in Tamilnadu (March 2020 -March 2021)**

Chennai, Chengalpettu, Tiruchirapally districts show extreme in the month of May.Coimbatore was moderate in the month of May, moved up to extreme in the month of January. Kanchipuram, Vellore which represented high in the month of May remains the same in January. Thiruvallur moved down its rates into moderate whereas Ranepet show low rate from high death rate. Madurai (moderate in May) Shivagangai (low in May) moved up to high ratio of death rate in the month of January. Virudhnagar, Theni, Nilgiris, low in May turned out moderate rates in March 2021.Tiruvallur changed from high to moderate. Kanyakumari, Tirunellvelli keep up the same place in both months.

**Conclusion**

Tamil Nadu was highly affected by COVID-19 in 2020. The major reasons are high population density, unaware of disease and not following the COVID-19 protocols from health department. The virus spread mainly from person to person. There are several ways this can happen; droplets or aerosols. When an infected person coughs, sneezes, or talks, droplets or tiny particles called aerosols carry the virus into the air from their nose or mouth. The comparative study displaces a clear difference in Madurai since there was only one death reported in the year 2020 March. If has shown a drastic change in the ensuing year as it had turned out to high in the second wave in Madurai and into extreme rates is Coimbatore, Chennai, Chengalpettu and Tiruchirapally.

### Acknowledgment

The authors gratefully acknowledge the RUSA-Phase-II (Rashtriya Uchchatar Shiksha Abiyan). Department of Geography, School of Earth and atmospheric science, Madurai Kamaraj University, Madurai, 625021 for their financial support in carrying out the publishing of this research work.

### Ethical approval

Ethical approval not required. This article does not contain any studies with human participants or animals performed by any of the authors.

### Conflict of Interest

On behalf of all authors, the corresponding author states that there is no conflict of interest.

### References

1. Chu J, Yang N, Wei Y, Yue H, Zhang F, Zhao J, *et al.* Clinical characteristics of 54 medical staff with COVID-19: a retrospective study in a single center in Wuhan, China. *Journal of medical virology*. 2020 Jul;92(7):807-13.
2. Klopfenstein T, Zahra H, Lepiller Q, Royer PY, Toko L, Gendrin V, *et al.* New loss of smell and taste: Uncommon symptoms in COVID-19 patients on Nord Franche-Comte cluster, France. *International Journal of Infectious Diseases*. 2020 Nov 1;100:117-22.
3. Rahamath Nisha R, Saravanabavan V, Sureshkumar R. Emerging COVID-19 Epidemiology in Tamil Nadu India using GIS. *International Journal of Contemporary Medical Research*. 2020;7(8):H10-7.
4. Gavriatopoulou M, Korompoki E, Fotiou D, Ntanasis-Stathopoulos I, Psaltopoulou T, *et al.* Organ-specific manifestations of COVID-19 infection. *Clinical and experimental medicine*. 2020 Nov;20(4):493-506.
5. Ding S, Liang TJ. Is SARS-CoV-2 also an enteric pathogen with potential fecal-oral transmission? A COVID-19 virological and clinical review. *Gastroenterology*. 2020 Jul 1;159(1):53-61.
6. Lewis D. COVID-19 rarely spreads through surfaces. So why are we still deep cleaning. *Nature*. 2021 Feb 4;590(7844):26-8.
7. Saravanabavan V, Abeesh P. Environmental health status of fishermen in Mahe district. *International Journal of Geography, Geology and Environment*. 2020;2(2):95-102.
8. Saravanabavan V, Shanmuganandan S. Leprosy and Multidrug therapy in Tamil Nadu, India: A Factor Analysis. *The Indian Geographical Journal*. 1998;73(1):41-50.
9. Eswari S, Saravanabavan V, Balaji D. Structural Equation Modelling Approach to Determine the Mother and Child Health Care in Madurai District, Tamil Nadu. *International Journal of Scientific Research in Science and Technology*. 2021;8(2):335-44.
10. RahamathNisha R, Saravanabavan V, Sureskumar R. Effects of Population in density and Air pollution on Covid -19 Morbidity and mortality in India using GIS. *International Journal of Contemporary Medical Research* 2021;8(8):H1-H11.ISSN (Online), 2393-915X, 2454-7379. DOI: <http://dx.doi.org/10.21276/ijcmr.2021.8.8.8>.
11. Saravanabavan V, Reejo RJ, Neethidevi A, Jayashree R. Travel and health care utilization pattern of patients in Vadipattipanchayat union: A micro level study using GIS. *Journal of Deccan Geographer*. 2006;44(2):97-108.
12. Sarvanabavan V, Shanmuganandan S. Identification of Health Care Delivery System for Paucibacillary Leprosy in Tannilnadu. *Calcutta*. 1997 Sep;3(59):216-24.
13. Saravanabavan V, Shanmuganandan S. Impact of MDTon changing scenario of Leprosy in Tamil Nadu. *The Journal of Region, Health and Health Care*. 1996;1(2):19-27.
14. Sheheersha SK, Saravanabavan V. Geo-Medical Analysis of the Detection of Cervical Pre-Cancer Cases Using Telemedicine System in Kerala State, India. *IOSR Journal of Dental and Medical Sciences*. 2020;10(11):12.
15. Saravanabavan V, Sudharsan R, Balaji D, Rahamath Nisha R. Patient's perception and epidemiological characteristics of dengue in Madurai city-using factor analysis. *International Journal of Mosquito Research*. 2014;1(2):18-24.
16. Balaji D, Saravanabavan V. Geo spatial variation of dengue risk zone in Madurai city using autocorrelation techniques. *GeoJournal*. 2021 Jun;86(3):1481-501.
17. Sheheersha SK, Reshma CU, Saravanabavan V. Sanjeevani Comprehensive Cancer Control Programme and Mobile TeleMedicine (SCCP&MTM) for rural poor: Design features, technical feasibility and usability. *International Journal of Applied Management Research (IJAMR)*. 2015;7(1):212-6.
18. Eswari S, Saravanabavan V, Balaji D. Infant neonatal and post neonatal mortality in Madurai district, Tamil Nadu, India: A Geomedical Study. *International Journal of Geography, Geology and Environment*. 2020;2(2):102-12.
19. Saravanabavan V, Reshma CU, Preethi S. Determinants of reproductive health in working women in Thrissur district, Kerala. *GeoJournal*. 2021 Feb;86(1):239-53.
20. Saravanabavan V, Balaji D, Rahamath Nisha R, Preethi S, Vadivel S. Geo-ecological association of dengue disease in Madurai city—using multivariate analysis. *International Journal of Mosquito Research*. 2020;7(2):37-45.
21. Saravanabavan V, Balaji D, Sudharsan R. A Geo-Medical Analysis of Chikungunya and Patients Environmental Perception in Madurai City. *Journal of JAC Journal of Science, Humanities, and Management*. 2014;1(2):111-20.
22. Saravanabavan V. Bicycles and health-a geo medical study of Madurai city. In *VeloAustralis and Velo-City'96*, International Bicycle Conference, Fremantle, Western Australia, 1996.
23. Saravanabavan V, Lekha CA, Aparna T, D Nisha RR, Balaji KK, Kanna SV. Spatio-temporal variation of dengue in Kozhikode District, Kerala: A medico geographical study. *International Journal of Mosquito Research*. 2021;8(1, Part B):130-40.
24. Saravanabavan V, Eswari S, VimalaVinnarasi J, Ganesan J, Sudharsan R. Spatial temporal variation of leptospirosis disease in Madurai city—Medico-geographical analysis. *International Journal of Geography, Geology and Environment*. 2020;2(1):21-7.
25. Vinothini C, Saravanabavan V, Balaji D. Travel pattern



- of health utilization to primary health care centres in Madurai district. International Journal of Geography Geology and Environment 2021;3 (2):144-151.
26. Saravanabavan V, Balaji D, Preethi S. Identification of dengue risk zone: A geo-medical study on Madurai city. GeoJournal. 2019 Aug;84(4):1073-87.
  27. Saravanabavan V. GIS analysis of pedestrian problem and spatial risk areas for each buffer zone in urban cities a case study of Madurai city in Tamilnadu, India. In 1st International symposium held on 19-21 April, at South Eastern University of Sri Lanka, 2011. <http://ir.lib.seu.ac.lk/handle/123456789/862>
  28. Saravanabavan V, Balaji D, Reshma CU, Sheheersha SK, Sudharsan R, VimalaVinnarasi J, *et al.* Urban disease ecology and its spatial variation of Chikungunya in Madurai City, Tamilnadu, India: a geo-medical study. GeoJournal. 2021 Oct;86(5):2335-50.
  29. Saravanabavan V, Aneesh P, Babu HM, Harieswari DM. Patient's perception and level of primary health care utilization in east block of Madurai North taluk: A geo-health study. International Journal of Geography, Geology and Environment. 2021;3(1):34-41.
  30. Eswari S, Saravanabavan V. A Geo Medical analysis of Diarrhoeal diseases among Children in Madurai City, Tamil Nadu, India. International Journal of Current Research. 2020;12(03):10684-9.
  31. Sudharsan R, Saravanabavan V, Devanathan D, Tech M. Patient Satisfaction and Perceptions about Quality of Healthcare at a Primary Healthcare Centre of Thanjavur District, Tamil Nadu. International Journal of Research in Science and Technology. 2019;9:2249-0604.
  32. Saravanabavan V. Patient's perception and travel behavior pattern in primary health care center in Haripad block-A micro Geo-medical study. Journal of Language in India. 2013 Apr 4;13(4):194-207.
  33. Rajendran S, Jayagopal P. Accessing Covid19 epidemic outbreak in Tamilnadu and the impact of lockdown through epidemiological models and dynamic systems. Measurement. 2021;169:108432pp.
  34. Priyadharshini CB, Priya S, Selvameena M, Waseemsha S, Muthurajesh E, Shalini M. Demographic profile of COVID-19 positive mothers & their outcome in government Rajaji hospital, Madurai, Tamilnadu—A cross sectional Study. Clinical epidemiology and global health. 2021;12:100864pp.
  35. Kumaravel SK, Subramani RK, Jayaraj Sivakumar TK, Madurai Elavarasan R, Manavalanagar Vetrichelvan A, Annam A, *et al.* Investigation on the impacts of COVID-19 quarantine on society and environment: Preventive measures and supportive technologies. 3 Biotech. 2020;10(9):1-24.