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Spread of COVID-19 and the Role of Distance-decay: A Case Study of West Bengal, India

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Abstract

Geographical phenomena are widely spread across space. Spatial distribution of such phenomena can be well understood by using various statistical methods. COVID-19 pandemic has also attained global recognition after its spatial diffusion through various mediums. The present paper tries to analyze the geographical spread of COVID-19 disease in West Bengal, India in terms of distance-decay function. The analysis has been carried out using multiple ring buffer in ArcGIS 10.8 and simple linear regression analysis which discloses that the density of COVID-19 cases is very high in the Central Business District (CBD) and diminishes while one moves from the CBD towards periphery.

Keywords: Distance-decay, COVID-19, Regression Analysis, West Bengal, Multiple ring buffer

1. Introduction

The outbreak of novel Coronavirus disease in 2019 (COVID-19) spread rapidly in China from its origin in Wuhan, Hubei Province, China (Chen et al., 2020) and eventually spread throughout the world. It has been recognized as a Global Pandemic by the World Health Organization (WHO). Several studies related to the spread of the disease suggests that the cities are more vulnerable to such pandemics (Khavarian-Garmsir et al., 2020), (Dettilo et. al., 2020), (Muggah et al., 2020), (Diez et al., 2020). "The high concentration of people and activities in cities make them vulnerable to various stressors such as natural and man-made disasters." (Sharifi & Khavarian-Garmsir, 2020). Spread of COVID-19 and its outbreak has been analyzed in relation to various factors such as environmental (Cartenì et al., 2020), socio-economic, demographic, healthcare resources (Buja et al., 2020), infrastructures (Nakada & Urban, 2020) etc. Its spread and impacts are concerned with the composition of the population, specially, population age structure (Dowd et al., 2020). In addition, its impacts and progression can also be correlated with population density, since living in closer proximity to one another is likely to imply a higher infection rate (Desmet & Wacziarg, 2021). Kolkata is one of the most densely populated cities in the world with 24,306 persons per sq. km.The first case of COVID-19 in the state of West Bengal had been found in Kolkata in 17 March, 2020 as a student who returned from United Kingdom (The Hindu, 17 March, 2020). Till the last weeks of April, the spread of COVID-19 was restricted to the airports only. But the community transmission has occurred in various district from the last two weeks of April 2020. Till 28th September, the state has reported a total of 1,567,573 cases out of which 18,764 persons were succumbed to death.

In the current study, an attempt has been made to analyze the spread of the COVID-19 pandemic in terms of distance from the city center. Waldo Tobler's first law of Geography rightly explains distance- decay as, "Everything is related to everything else, but near things are more related than distant things" (Tobler, 1970). Distance plays crucial role in the distribution of ideas, technology, population, and interaction (Eldridge, 1991). Colin Clark (1951) devised a negative exponential model, where he revealed that the residential density of an area is negatively correlated to distance from the city center. Notably, as one moves away from the city center, the population density goes on decreasing. This proposition gave us the concept of concentric development of a city or a residential area where the rate of population density decreases similarly in all the directions, results in the growth of a circular city with Central Business District (CBD) at the center (Clark, 1951). The relationship devised by Clark has been applied in the context of the Density of COVID-19 infected persons that has been detected in the state of West Bengal by taking Kolkata district as the CBD. This paper is therefore an attempt to examine the applicability of Distance-decay model in the distribution of COVID-19 cases across West Bengal, India.

2. Study Area

In this study, the aim is to investigate the applicability of Distance-Decay model envisaged by Colin Clark (1951) in the event of the density of COVID-19 cases that have been detected in the state of West Bengal. For this purpose, we have taken West Bengal as our study area. The districts of West Bengal have been considered as the spatial units on which the whole analysis process depends. Clark has taken the area around a Central Business District as the study area. But we have considered the districts as the periphery urban areas and the Kolkata district as the Central Business District.

West Bengal is situated in the Eastern part of India covering up an area of 88,752 sq. km extending from the foothills of the Himalayas to the Bay of Bengal. It lies between 85°50'E to 89°50' E longitude and 21°25′N to 27°13′N latitude (Fig 1). The eastern boundary of West Bengal is covered by Bangladesh and Assam. To the north, Sikkim and Bhutan covers the boundary. In the western boundary, there lies Bihar, Jharkhand and Orissa and the southern part is covered up by the Bay of Bengal. The state enjoys tropical hot, humid and monsoon climate. 13.93% area out of the total area is covered by natural vegetation. (Biswas et al., 2021)

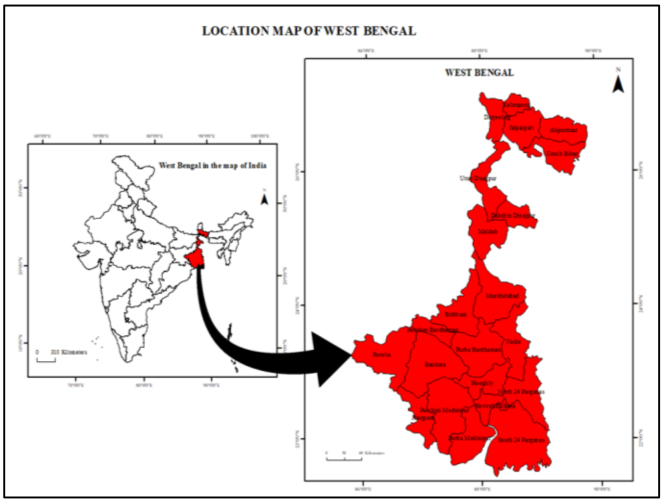


Figure 1 Location Map of West Bengal

Source: Authors' own work

The state has 23 districts, out of which South 24 Parganas is the largest and Kolkata is the smallest. The total population of the state is 91,347,736 according to Census of India, 2011 with a population density of 950 persons per sq. km. The capital of the state, Kolkata is the third-largest urban agglomeration in India. Kolkata districts have a 100% urbanization level. The average urbanization level of the state is 28.78%. The sex ratio is 934 and the literacy rate is 74.04%.

3. Methodology

3.1 Data Collection

As the collection of primary data is not possible in the current situation. So, the study has to be completed on the basis of secondary data collected from various online sources. Both, Central and the State government of West Bengal has been publishing COVID-19 related data in their websites. Data from February 2020 to 15 May 2021 has been collected from the Health and Family Welfare Department, Government of West Bengal. The websites that have been visited for collecting COVID-19 data are:

1. https://www.covid19india.org/state/WB
2. https://www.covid19india.org

Data on population has been collected from Census of India website:

1. https://censusindia.gov.in/DigitalLibrary/MFTableSeries.aspx (Primary Census Abstract Tables)

3.2 Methods

Colin Clark (1951) propounded an exponential model for describing the pattern of population density distribution (Tse, 1976). His model has been further utilized by various researchers in various fields of knowledge. Clark's model is:

$$Dx = Do\ e^{-bx}$$

(Clark, 1951)

Where, Dx is the population density at distance x, Do is the assigned central population density, e is the exponent of distance and b is the density gradient. Clark had used two generalisations for his study of population density and distance in various cities around the world. These are:

a. In every large city, excluding the central business zone, which has few resident inhabitants, we have districts of dense population in the interior, with density falling off progressively as we proceed to the outer suburbs.

b. In most (but not all) cities, as time goes on, density tends to fall in the most populous inner suburbs, and to rise in the outer suburbs, and the whole city tends to "spread itself out."

"The model shows a non-linear relationship between the distance and population density. In order to find out a linear relationship, a logarithmic transformation of the distance-decay equation is necessary". (Das, 2020)

Thus,

$$\log_e d(x) = \log_e(d_0 e^{-bx})$$

Or

$$\log_e d(x) = \log e d_0 - bx \cdot \log_e e \text{ (Since } \log_e e = 1\text{)}$$

Thus,

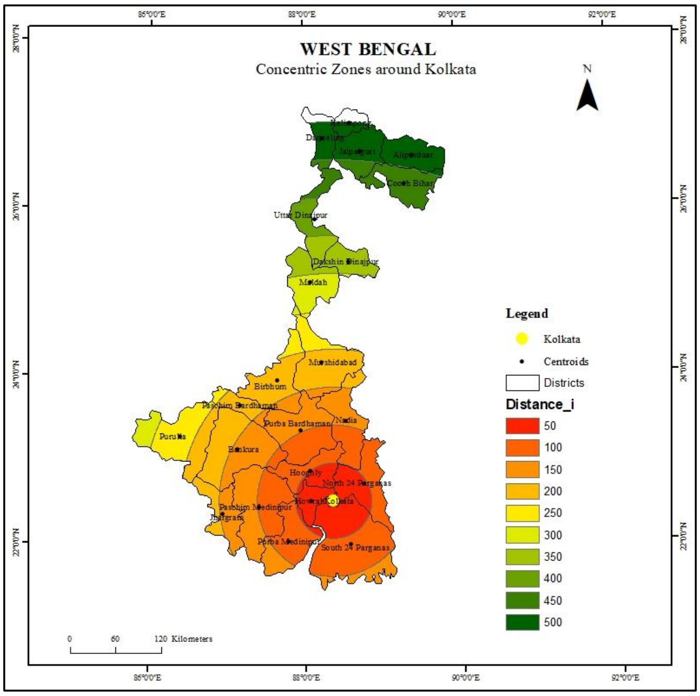
$$\log_e d(x) = \log e d_0 - bx$$

Now, if we write $\log_e d(x)$ as $\hat{y}$ and $\log e d_0$ as a. Then, $\hat{y} = a + bx$, and it is a linear equation of distance-decay Model. Clark envisaged that the population density of a city decreases as the distance increases from the city centre. The steepness of the decline in density changes over time. The decline of density from the city centre largely depended upon the co-efficient b. A high value of b results in sharp decline of density with the increase in distance from the centre which is often called as a compact city. A low value means gradual decline in density resulting in the city to be more spread out. Clark has indicated transport as one of the basic factors for which the decline in density changes (Tse, 1976).

In his methodology, Clark had drawn a series of concentric rings about the centre of the city at an interval 1 mile of radius. Where these circles cut the census tracts, he made arbitrary apportionments of the population. This was done by considering the proportion of land area lying in each ring exclusive of the open spaces. The total population and the average density for each ring had been calculated then. A diagram was then prepared where the horizontal axis represented the distance from the city centre and the vertical axis represented the measured density in a natural logarithm. The parameters D_o and b were obtained by using regression analysis using the logarithmic form of equation (Tse, 1976).

In this study, data collected from various sources have been classified to fulfil the demand of the analysis process. We have followed the methodology used by Clark. Recent map of West Bengal with its newly formed districts has been digitized in ArcMap 10.8. The data related to COVID-19 and population has been classified in MS excel 2013. It is worth mentioning that new districts have been formed after 2011 census. Therefore, the population data for the new districts are not readily available. To compensate this, we have bifurcated the population data of the old district to two separate new districts which have been formed in the later period. All other map works have been done using ArcMap 10.8. Concentric circles around Kolkata district have been created using Multiple Buffer Ring analysis (Fig 2). The plotting of the case density for each ring against average distance of each ring has been done in MS excel 2013. Case density has been found out by dividing the total cases (sum of the number cases found in the census tracts which fall under a particular ring) of each ring by the total area of the ring. (Table 1).

Figure 2. Concentric zones around Kolkata district



Source: Authors' own work

Table 1. Zone wise density of COVID-19 infected persons

Zones	Distance in KM	Average Distance	Districts Under the zones	Total Population affected by COVID-19	Total Area	Density of Infected Population (Persons/sq. km)
1	0	0	Kolkata	316229	185	1709
2	0-50	41.66	North 24 Parganas, Howrah, Hooghly	506069	8640	59
3	50-100	79.62	Purba Medinipur, South 24 Parganas, Paschim Medinipur	214254	16299.17	13
4	100-150	125.3	Nadia, Purba Bardhaman, Bankura, Jhargram	160771	19279.33	8
5	150-200	178.13	Murshidabad, Birbhum, Paschim Bardhaman	131758	11472.17	11
6	200-250	218.09	Purulia	19349	6259	3
7	250-300	290.8	Maldah	33124	3733	9
8	300-350	317.1	Dakshin Dinajpur	17429	2219	8
9	350-400	372.1	Uttar Dinajpur	19698	3140	6
10	400-450	429.9	Cooch Bihar	28863	3387	5
11	450-500	477.57	Alipurduar, Jalpaiguri, Kalimpong, Darjeeling	119963	9363.5	13

Source: Census of India, https://www.covid19india.org/state/WB and Author's own calculation (as of 28th September 2021)

4. Results and Discussion

The graph obtained by plotting the average density of COVID-19 cases against the average distance of each ring shows a negative correlation trend. In the linear model, the a value is 255.74 and the b value is -0.1534 and the value of R^2 is 0.2391 which suggests that 23.91 per cent of variation of COVID-19 cases is explained by the distance from the Central Business District i.e., Kolkata District (table 2).

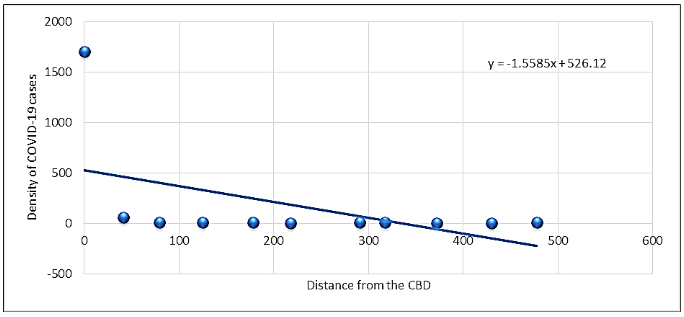
Table 2. Density gradient statistics

Independent Variable	Explanatory Variable: Density of COVID-19 cases		
	Model	Correlation coefficient	R² value
Average distance	y = -1.5585x + 526.12	-0.4889	0.2391

Source: Author's own work

The trend line so obtained, slopes towards its right (figure 3). The maximum expected density of cases is at the Kolkata district which is 526 persons per sq. km whereas the minimum expected density is found to be in the farthest point which shows a negative value of -218 persons per sq. km. The observed density in the Kolkata is much higher than the expected density which signifies a very high interaction among the people living there. This high interaction is due to good transportation and communication networks, overcrowding in markets etc. on the other hand peripheral regions show values higher than the expected values because these regions lie in the areas where the transportation is quite developed due to interstate connectivity facility. But the middle areas show values which are much lower than the expected values. In these regions, transport connections are not well developed. Remote areas such as, delta, wetlands, forests, villages are largely located in these zones. It clearly proofs that the outbreak of COVID-19 disease is higher in those areas where the transportation system is well developed, where the interaction between people is much higher.

Figure 3. Density Gradient of COVID-19 cases in West Bengal, India



Source: Author's own work

5. Conclusion

As mentioned earlier, this paper aims at giving a distance-decay model-based description of COVID-19 outbreak in the state of West Bengal. The disease reaches every district in the state although there is much disparity in terms of frequency of occurrence of cases across districts. The model aptly defines its prospective of decay of a geographical phenomenon with increase in distance. More an area is well connected with transport lines, greater is the chance of outbreak of COVID-19 disease. Therefore, it is suggested to restrict the inter-district flows i.e., movement of people to avoid further spread of the pandemic. The state governments have taken bold steps like lockdown and curfew in various states. These measures will surely reduce the rate of spread of the disease. Reducing the level of interaction between people is the sole measure that can be initiated by any type of administrative unit.

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