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AHP and GIS-based Risk Zonation of COVID-19 in North East India

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Abstract

On 31st December 2019, a novel virus was reported from Wuhan City of Hubei Province of China, and later it was recognized as SARS-COV-2 (COVID-19). As the virus is highly human to human contagious, it has spread worldwide within a very short time. Since 24th March 2020, after the first reported case in North East India, the total confirmed cases reached up to 4,633 on 11th June 2020. In this work, an attempt has been made to delineate risk zones of COVID-19 in North East India using the Analytic Hierarchy Process (AHP) and overlay analysis in Geographical Information System (GIS). The evaluation is based on 14 criteria that were classified into promoting and controlling factors. The promoting factors include population size, population density, urban population, elderly population, population below the national poverty line, and percentage of marginal workers. In contrast, the controlling factors include available doctors, other health workers, public health facilities, available beds, governance index (composite and health), and testing laboratories. The results were classified into very high, high, moderate, low, and very low risk zones. Most densely populated states with massive pressure on health facilities are likely to have a higher risk of COVID-19. Assam, Tripura, Meghalaya, and Nagaland show a high COVID-19 risk, which constitutes almost 76.93% of the North East India population, covering 48.80% of surface area. The states under a moderate risk zone include 6.92% of the population over 8.52% of the area. Lastly, 16.15% of the people living over 42.69% of the total area belong to the states with a lower risk zone.

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Introduction

The World Health Organization (WHO) country office has been informed about the pneumonia cases of unknown etiology detected in Wuhan City, Hubei Province of China on 31st December 2019.[1] Unexpectedly, it spread to different regions of China as well as other countries across the world, despite China's considerable efforts to restrain the infection within Hubei.[2] Later, the epidemic was recognized as novel coronavirus of 2019 or SARS-CoV-2 resulting in the disease COVID-19.[3] On 31st January 2020, the WHO declared coronavirus as a public health emergency of international concern.[4] It is a member of a large family of coronaviruses resulting in Severe Acute Respiratory Syndrome (SARS) and Middle East Respiratory Syndrome (MERS).[5] Compared to the SARS-CoV (2002/2003) and the MERS-CoV (2012-2014), COVID-19 has remarkably faster human-to-human transmission as it took only 48 days to infect 1000 people, whereas MERS took around 2½ years and SARS took about four months to reach that figure.[2] Based on the global spread of COVID-19, the WHO declared it as a pandemic.[6] In general, the virus is capable of infecting people of all ages, but the population with above 60 years of age and people with heart disease, asthma, diabetes, chronic lung disease, kidney disease, etc. are at increased risk of severity of COVID-19.[7]

Although health facilities and socio-economic conditions of the people have drastically improved since independence, human development and its growth are destitute in North East India (NEI, hereafter). In fact, it is lower than many underdeveloped nations of the world.[8] Since the initial detection of COVID-19 in Kerala on 30th January 2020, it had spread to many parts of the country. Presently, there are 276,583 confirmed cases, 7,745 deaths, and 135,205 cured cases of COVID-19 in the country as on 10th June 2020.[9] The cases have increased tremendously from 519 confirmed cases with ten deaths as of 24th March 2020 to date. NEI is located in the easternmost part of the country, which is inhabited by 3.88% of the country's total population. The earliest infection of COVID-19 in NEI was reported from Manipur on 24th March 2020,[10] and it took only 78 days to reach 4,433 confirmed cases as of now.[9] The number of cases has been increasing despite the entire nation been put under lockdown (in different phases) from 25th March 2020 by the central government.[11] Due to the absence of a vaccine, avoidance of touching the nose, eyes, and mouth, frequently washing hand, the practice of hand sanitizers, covering of face with a proper quality mask, social distancing, and respiratory hygiene are the quotidian measures to stay safe from the virus.[5] The inherent large-scale regional disparities in terms of demography and socio-economic characteristics, along with depressed health conveniences, are likely to exacerbate the pandemic situation in the region. Therefore, an effort has been made to delineate the risk zones of COVID-19 in NEI using the data gathered from various sources of the Government of India applying Analytic Hierarchy Process (AHP) and Geographical Information System (GIS).

Materials and Methods

Study Area

The study area constitutes 8 NEI states, namely Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura (Fig. 1). The region is characterized by mountains, hills, and plains with rich culture and biological diversity. NEI shares an international boundary with Nepal, China, Bhutan, Myanmar, and Bangladesh and a state boundary with West Bengal.

Methodology

Based on promoting and controlling factors of COVID-19, fourteen thematic layers (Table 1 & Fig. 2) have been considered to carry out the present study using ArcGIS 10.3 software. AHP was used to assign the weights for each individual reclassified layer (generated after converting ancillary data into raster format) to perform the Weighted Overlay technique to generate the final risk zonation map of the study area.

Analytic Hierarchy Process (AHP)

As per the literature review of available materials and expert opinions, Saaty's fundamental 9 - points scale values were assigned to each thematic layer according to their potentiality on generating risk zones of COVID-19. The weights assigned to different layers were normalized and checked for consistency (consistency ratio) as suggested by Saaty (1980).[23] The consistency ratio reflects the probability that the matrix ratings were randomly generated. The consistency ratio was derived using the following equations:

Consistency Index (CI) = $(\lambda_{max}-n)/(n-1)$ ...(1)

Where, λ_{max} is the largest eigenvalue of the pairwise comparison matrix,

'n' represents the total number of parameters.

Consistency Ratio (CR) = (Consistency Index (CI)/ (Random Consistency Index (RI) ...(2)

The value of the Random Consistency Index (Table 2) was obtained from Saaty (1980).[23] For consistent weights, the value of CR should lie between 0 and 0.1 (i.e., 10%); otherwise, the corresponding weights should be re-evaluated. In this study, the consistency ratios of pairwise comparison matrix for promoting and controlling factors were 0.044 and 0.025, indicating that the comparisons of evaluation criteria are consistent.

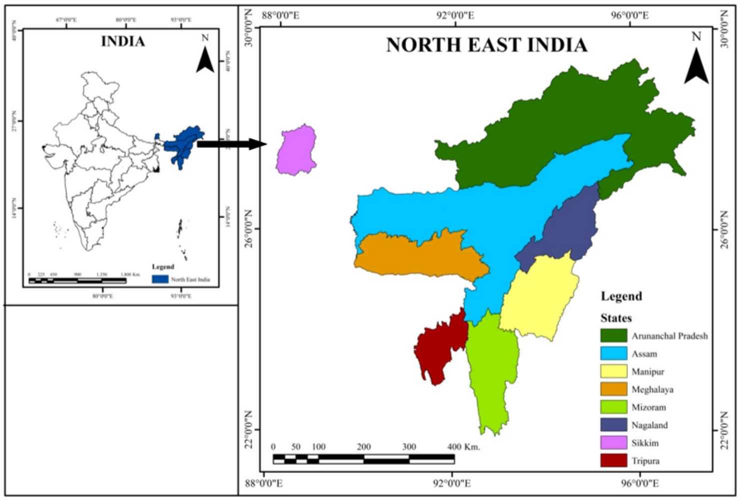

Fig. 1: Location map of the study area

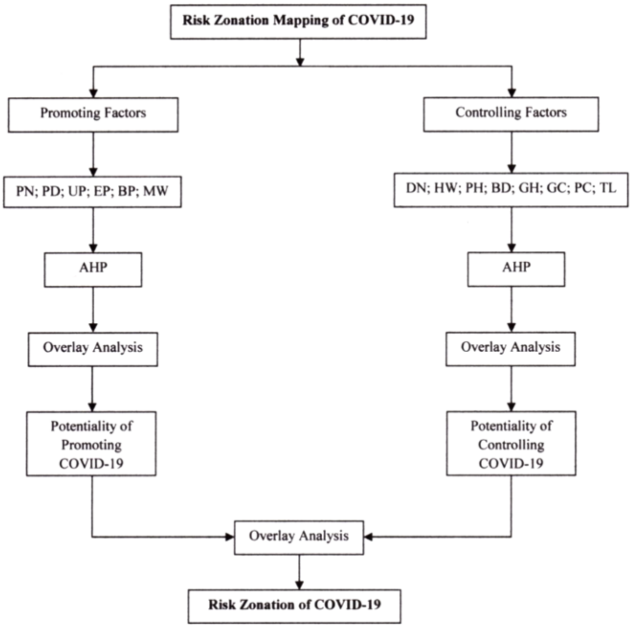

Fig. 2: Methodology used for assessing the risk zonation of COVID-19

Table 2: Random Consistency Indices (RI) adopted from Saaty, (1980 p. 21)[23]

N	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Delineation of Risk Zones

The factors (promoting and controlling) undertaken to carry out the study are considered to have the potentiality to influence risk during any kind of pandemic situation (Annexure 1 & 2). These influencing factors are weighted as per their response to taking risk where the higher value in promoting factors represents a high potential to promote risk, and the lower value in controlling factors represent high potentiality to defeat the risk. A weighted overlay analysis was executed using both the factors (Fig. 2) in the GIS environment to delineate the risk zones using the following formula:

$$PF = (PN_w PN_r)+(PD_w PD_r)+(UP_w UP_r)+(EP_w EP_r)+(BP_w BP_r)+(MW_w MW_r).$$

$$CF = (DN_w DN_r)+(HW_w HW_r)+(PH_w PH_r)+(BD_w BD_r)+(GH_w GH_r)+(GC_w GC_r)+(PC_w PC_r)+ (TL_w TL_r).$$

$$RZ = (PF_w PF_r)+(CF_w CF_r)$$

[Where, PF: promoting factor; CF: controlling factor; RZ: risk zone; PN: population size; PD: population density; UP: urban population; EP: elderly population; BP: population below national poverty line; MW: % of the marginal worker; DN: availability of doctors; HW: other health workers; PH: public health facilities; BD: bed available in public health facilities; GH: good governance health index; GC: good governance composite index; PC: per capita income; TL: available testing laboratories].

Results and Discussion

All the sub-criteria of selected thematic layers were assigned relative ranks based on their influence in promoting and controlling the situation (Table 4 & 6). The overall potentiality of promoting and controlling the COVID-19 pandemic has been generated through overlay analysis of the layers. Finally, the risk zones were delineated out of the promoting and controlling layers by providing equal importance (Table 7).

Promoting Factors

Among the promoting factors (Annexure-1) that would increase the cases of COVID-19 in NEI, the dominant factors (Table 3) are the concentration of urban population (24.57%), followed by population density (22.18%), population below national poverty line (25.19%), population size (13.89%), percentage of marginal workers (11.09%) and percentage of the elderly population (8.70%). As the nature of the virus is human-to-human contagious, the factors that promote human gathering and make trouble to stay inside the home for a longer time get higher weights of influence. The results based on relative weights (Table 4) and overlay analysis (Fig. 4) vary from 2.70-5.56 that was categorized into five classes using Natural Breaks (Jenks) method and represented as very high (4.50-5.56), high (3.99-4.50), moderate (3.30-3.99), low (2.88-3.30) and very low (2.70-2.88).

Table 3: Pairwise comparison matrix of promoting factors

	PN	PD	UP	EP	BP	MW	Normalized Weight	In %
PN	1.00	0.50	0.50	2.00	0.50	2.00	0.1389	13.89
PD	2.00	1.00	0.50	2.00	2.00	2.00	0.2218	22.18
UP	2.00	2.00	1.00	2.00	1.00	2.00	0.2457	24.57
EP	0.50	0.50	0.50	1.00	0.50	0.50	0.0870	8.70
BP	2.00	0.50	1.00	2.00	1.00	2.00	0.1957	19.57
MW	0.50	0.50	0.50	2.00	0.50	1.00	0.1109	11.09

[PN: size of population; PD: pressure of population; UP: urban population; EP: elderly population; BP: population of below national poverty line; MW: % of marginal worker]

Table 4: Relative weights of promoting factors

Sl. No.	Theme	Classes	Intensity	Ranks	Normalized Weights	Influence (%)
1.	PN ('000)	Upto 1000	VL	1	0.1389	13.89
		1000 - 2000	L	2		
		2000 - 3000	ML	3		
		3000 - 4000	M	4		
		4000 - 5000	MH	5		
		5000 - 6000	H	6		
		Above 6000	VH	7		
2.	PD	Upto 50	VL	1	0.1773	17.73
		50 - 100	L	2		
		100 - 150	ML	3		
		150 - 200	M	4		
		200 - 250	MH	5		
		250 - 300	H	6		
		Above 300	VH	7		
3.	UP	Upto 10	VL	1	0.2457	24.57
		10 - 20	L	2		
		20 - 30	ML	3		
		30 - 40	M	4		
		40 - 50	MH	5		
		50 - 60	H	6		
		Above 60	VH	7		
4.	EP	Upto 2	VL	1	0.0870	8.70
		2 - 4	L	2		
		4 - 6	ML	3		
		6 - 8	M	4		
		8 - 10	MH	5		
		10 - 12	H	6		
		Above 12	VH	7		
5.	BP	Upto 10	G	1	0.1957	19.57
		10 - 20	AG	2		
		20 - 30	F	3		
		30 - 40	AF	4		
		40 - 50	P	5		
		50 - 60	AP	6		
		Above 60	B	7		
6.	MW	Upto 2	G	1	0.1109	11.09
		2 - 4	AG	2		
		4 - 6	F	3		
		6 - 8	AF	4		
		8 - 10	P	5		
		10 - 12	AP	6		
		Above 12	B	7		

[VL: very low; L: low; ML: moderately low; M: moderate; MH: moderately high; H: high; VH: very high; G: good; AG: approaching to good; F: fair; AF: approaching to fair; P: poor; AP: approaching to poor; B: bad]

Large population size with high population density was found to promote a high risk of COVID-19 in Assam, followed by Tripura. A moderate risk of promoting the pandemic was found in Mizoram, Manipur, and Nagaland. Sikkim and Meghalaya were found to have low risk, while Arunachal Pradesh has a very low risk of promoting COVID-19 (Fig. 4).

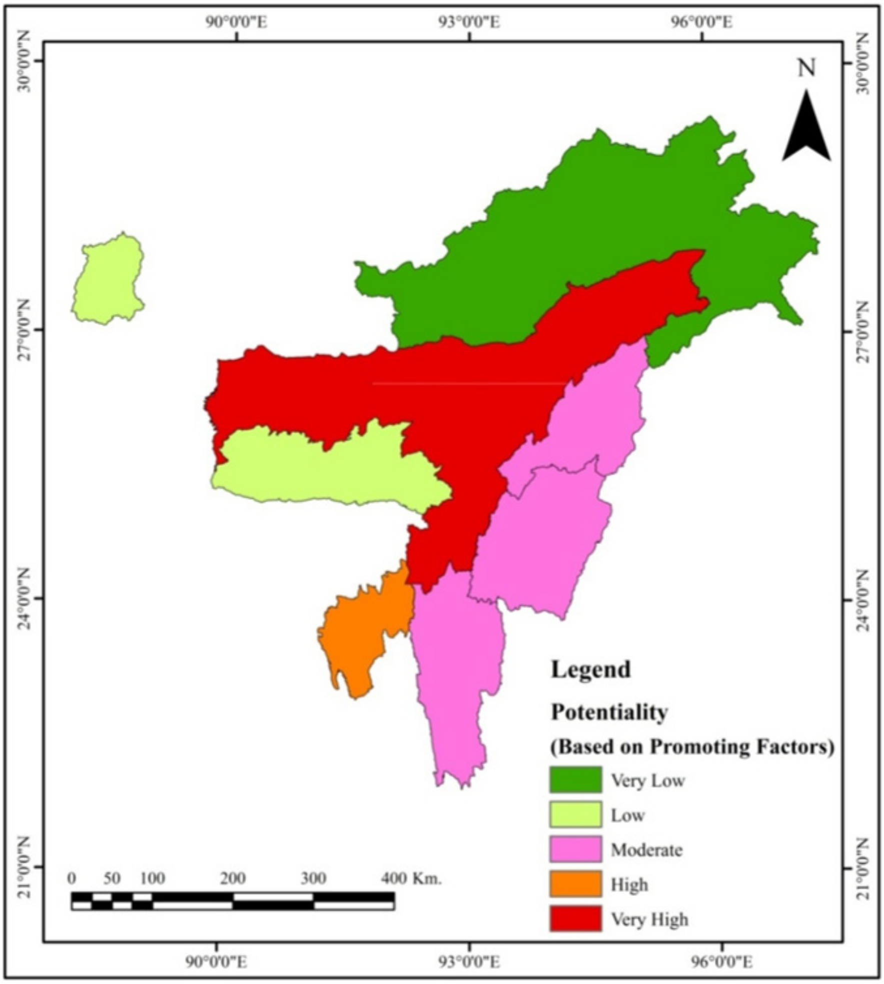

Fig. 3: Potentiality of risk based on promoting factors

Controlling Factors

Among the controlling factors (Annexure-2), the most influencing factors were availability of doctors (24.01%) and available testing laboratories (24.01%) followed by other health workers (14.84), bed available in public health facilities (10.99%), good governance health index (8.08%), number of public health facilities (7.27%) per capita income (6.40%) and good governance composite index (4.40%) as shown in Table 5. The results based on relative weights (Table 6) and overlay analysis (Fig. 6) ranges from 4.72 to 6.31, which was categorized into five classes viz. very high (4.72-5.22), high (5.22-5.61), moderate (5.61-5.86), low (5.86-6.01) and very low (6.01-6.31).

The results show that Assam and Meghalaya have very low potentiality while Tripura has a low potentiality to control the present pandemic situation. A moderate potentiality to control the situation was found in Arunachal Pradesh, and Nagaland and Manipur have high potentiality while Sikkim and Mizoram have a very high potentiality to control COVID-19.

Table 5: Pairwise comparison matrix of controlling factors

	DN	HW	PH	BD	GH	GC	PC	TL	Normalized Weights	In %
DN	1.00	2.00	4.00	3.00	3.00	4.00	3.00	1.00	0.2401	24.01
HW	0.50	1.00	3.00	2.00	2.00	3.00	2.00	0.50	0.1484	14.84
PH	0.25	0.33	1.00	0.50	1.00	2.00	2.00	0.25	0.0727	7.27
BD	0.33	0.50	2.00	1.00	2.00	3.00	2.00	0.33	0.1099	10.99
GH	0.33	0.50	1.00	0.50	1.00	2.00	2.00	0.33	0.0808	8.08
GC	0.25	0.33	0.50	0.33	0.50	1.00	0.50	0.25	0.0440	4.4
PC	0.33	0.50	0.50	0.50	0.50	2.00	1.00	0.33	0.0640	6.40
TL	1.00	2.00	4.00	3.00	3.00	4.00	3.00	1.00	0.2401	24.01

[DN: availability of doctors; HW: other health workers; PH: public health facilities; BD: bed available in public health facilities; GH: Good Governance Health Index; GC: Good Governance Composite Index; PC: Per Capita Income; TL: available testing laboratories]

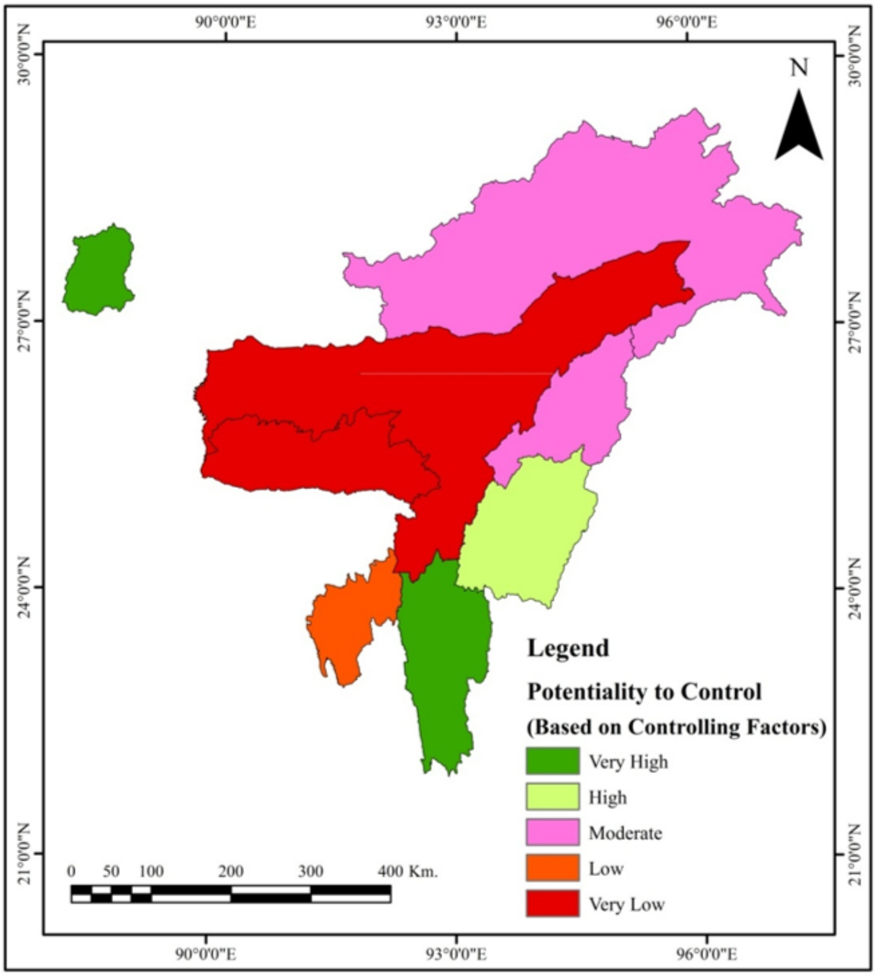

Fig. 4: Potentiality of controlling the pandemic

Table 6: Relative weights of controlling factors

Sl. No.	Theme	Classes	Intensity	Ranks	Normalized Weights	Influence (%)
1.	DN	Upto 30	VL	7	0.2401	24.01
		30 - 60	L	6		
		60 - 90	ML	5		
		90 - 120	M	4		
		120 - 150	MH	3		
		150 - 180	H	2		
		Above 180	VH	1		
2.	HW	Upto 150	VL	7	0.1484	14.84
		150 - 300	L	6		
		300 - 450	ML	5		
		450 - 600	M	4		
		600 - 750	MH	3		
		750 - 900	H	2		
		Above 900	VH	1		
3.	PH	Upto 4	VL	7	0.0727	7.27
		4 - 8	L	6		
		8 - 12	ML	5		
		12 - 16	M	4		
		16 - 20	MH	3		
		20 - 24	H	2		
		Above 24	VH	1		
4.	BD	Upto 60	VL	7	0.1099	10.99
		60 - 120	L	6		
		120 - 180	ML	5		
		180 - 240	M	4		
		240 - 300	MH	3		
		300 - 360	H	2		
		Above 360	VH	1		
5.	GH	Upto 0.3	B	7	0.0808	8.08
		0.3 - 0.4	AP	6		
		0.4 - 0.5	P	5		
		0.5 - 0.6	AF	4		
		0.6 - 0.7	F	3		
		0.7 - 0.8	AG	2		
		Above 0.8	G	1		
6.	GC	Upto 3.3	B	7	0.0440	4.40
		3.3 - 3.6	AP	6		
		3.6 - 3.9	P	5		
		3.9 - 4.2	AF	4		
		4.2 - 4.5	F	3		
		4.5 - 4.8	AG	2		
		Above 4.8	G	1		
7.	PC	Upto 80000	VL	7	0.0640	6.40
		80000 - 120000	L	6		
		120000 - 160000	ML	5		

		160000 - 200000		M	4	
		200000 - 240000		MH	3	
		240000 - 280000		H	2	
		Above 280000	VH	1		
8.	TL	Upto 1	VL	7	0.2401	24.01
		1 - 2	L	6		
		2 - 3	ML	5		
		3 - 4	M	4		
		4 - 5	MH	3		
		5 - 6	H	2		
		Above 6	VH	1		

[VL: very low; L: low; ML: moderately low; M: moderate; MH: moderately high; H: high; VH: very high; B: bad; AP: approaching to poor; P: poor; AF: approaching to fair; F: fair; AG: approaching to good; G: good]

A Glance at COVID-19 in NEI

Since the first infection of COVID-19 in Manipur on 24th March 2020, it took around 24 days to reach 50 confirmed cases. It took only 18 days to reach 100 confirmed cases on 4th May 2020 then it took just four days to double the figure from 100 to 200 confirmed cases. An unexpected rise in the COVID-19 patients in Tripura and steady infections in Assam has resulted in the number to cross 200 marks.[24] In Assam, the first COVID-19 case was detected on 31st March 2020 from Karimganj district, which was the 3rd confirmed case in NEI after one case each from Manipur and Mizoram.[25] At present, most of the reported cases of COVID-19 are from the quarantine centers, and the death rate from COVID-19 is very low (Fig. 7) with only six deaths recorded out of 4,633 confirmed cases as on 11th May 2020.[9] Among the states, Assam has the highest 3,092 confirmed cases of COVID-19 as on 11th June 2020 (Fig. 8). The total number of active cases in Assam was 1,893, followed by Tripura with 655 cases.

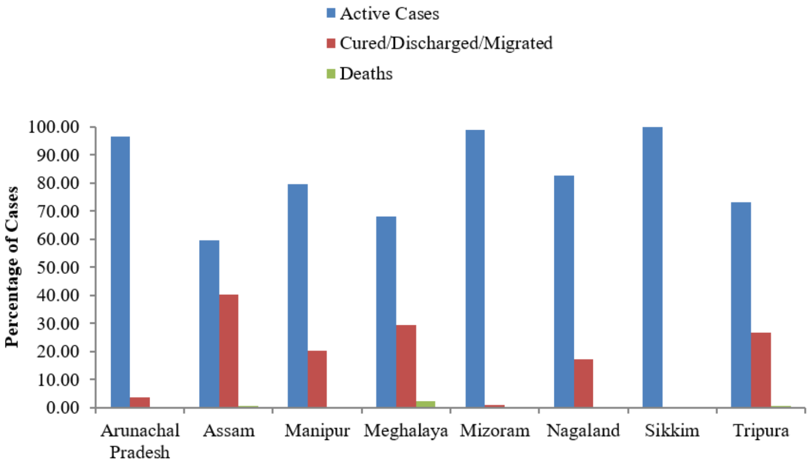

Fig. 5: Percentage of active, cured, and deaths of COVID-19 as on 11th June 2020

Risk Zonation Mapping

Based on the relative weights of promoting and controlling factors (Table 7), the potential risk zones of COVID-19 generated thereof has been shown in Fig. 9. The result of the map varies from 1.50 to 5.01, which were categorized into five risk zones viz. Very Low (1.50-1.67), Low (1.67-2.04), Moderate (2.04-2.99), High (2.99-3.99) and Very High (3.99-5.01).

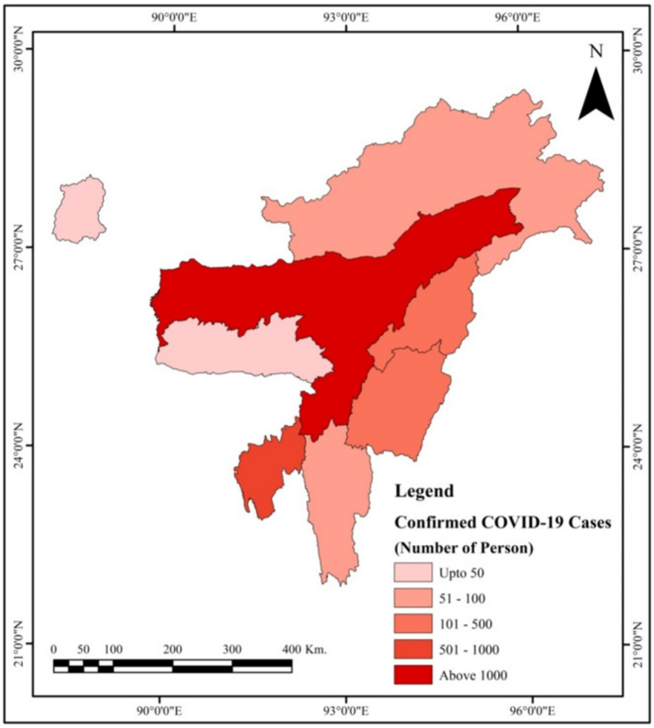

Fig. 6: Confirmed cases of COVID-19 as on 11th June 2020

Table 7: Relative weights of risk zonation

Sl. No.	Theme	Classes	Ranks	Influence
1.	Promoting Factor	VL	1	0.5 (50%)
		L	2	
		M	3	
		H	4	
		VH	5	
2.	Controlling Factor	VL	5	0.5 (50%)
		L	4	
		M	3	
		H	2	
		VH	1	

[VL: very low; L: low; M: moderate; H: high; VH: very high]

Based on factors considered in the study, the predictions revealed that Assam and Tripura would fall in the very high risk zone of COVID-19 and Meghalaya and Nagaland in high risk zone. Manipur is likely to have a moderate risk of COVID-19. Comparatively, Arunachal Pradesh and Mizoram are likely to have low risk, whereas Sikkim has a very low risk of COVID-19. The regional disparities in population characteristics and public health facilities in Assam and Tripura are likely to contribute to COVID-19 cases rapidly. Both the states scored poorly in terms of controlling factors and likely to fail in containing the pandemic in the long run.

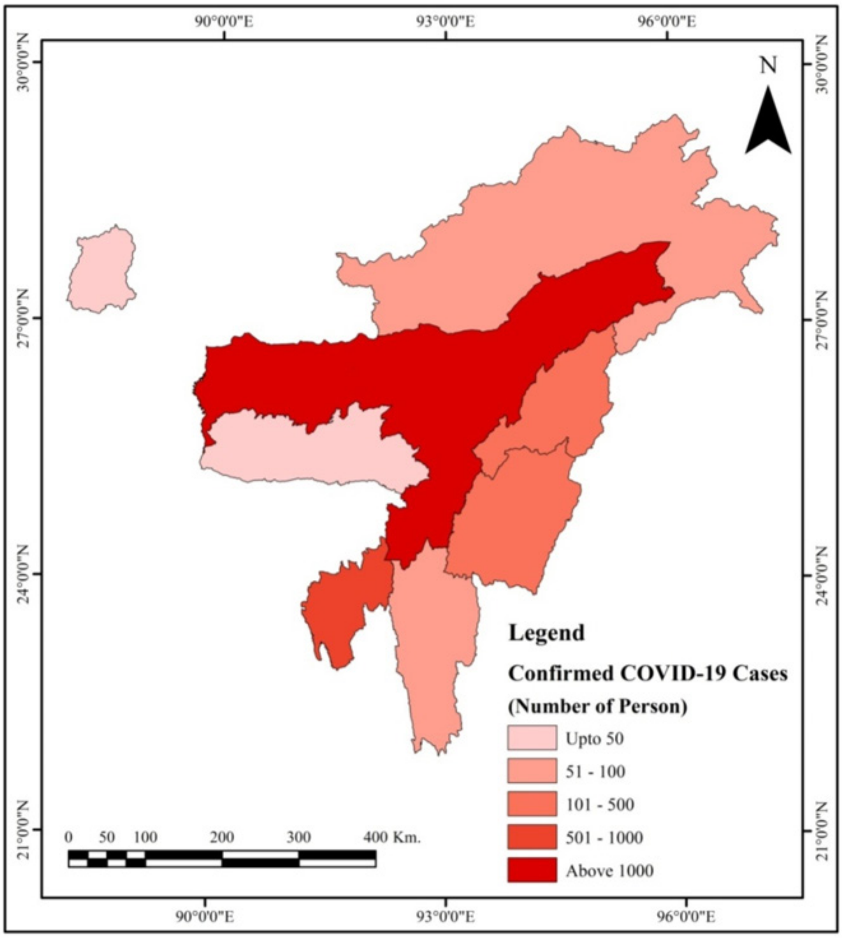

Fig. 7: Potential risk zones of COVID-19 in North East India

Overall, Assam and Tripura constitute 49.40% of the total population of NEI. Although the confirmed COVID-19 cases at present are low, the severity of COVID-19 is likely to amplify at a much faster rate in the coming days. A total population of 76.93% falls under high risk zone, 6.92% under moderate risk zone, 12.69% under low risk zone, and 3.46% in a very low risk zone. A general trend of high risks in densely populated states compared to sparsely populated states was found. The results also show a high to very high risk of COVID-19 in the states with significantly less testing laboratory facilities coupled with inadequate public health facilities. Further, the states with a high percentage of below poverty line population and marginal workers may also contribute to the rising cases of the pandemic. Guwahati (the largest urban center of NEI) plays a vital role in increasing cases of COVID-19. At present, the Himalayan hilly states (Arunachal Pradesh, Mizoram, and Sikkim) have reported lesser cases of COVID-19 due to remote location and inaccessibility. These states have the opportunity of more time to organize themselves in fighting against COVID-19 through imposing effective measures and precautions.

Concluding Remarks

The study shows the applicability of AHP and GIS in delineating the risk zones of COVID-19 in North East India. The urban population, population density, population below the national poverty line, population size, the proportion of marginal workers, and the percentage of the elderly population appears to play an essential role in promoting Covid-19 in North East India. While the influence of testing laboratory, availability of doctors, other health workers, bed available in public health facilities, and good governance health index plays an essential role in controlling COVID-19 in the region. Assam and Tripura have a higher risk of promoting COVID-19 transmission in a very short period. On the other hand, Assam, Meghalaya, and Tripura have very weak means to control the severity of COVID-19. Overall, Assam, Tripura, Meghalaya, and Nagaland have a high risk of COVID-19, while Mizoram, Arunachal Pradesh, and Sikkim have a lower risk. Therefore, the respective state governments need to assess their strengths and weaknesses and develop strategic plans to fight against the pandemic. Lastly, frequent testing of COVID-19, immediate quarantine of suspected people, proper social distancing, and regular practice of face mask and hand sanitizer may decelerate the transmission rate of the disease in the absence of a vaccine of COVID-19.

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Conflict of Interest

There is no conflict of interest in this manuscript.

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