Urban Expansion Influence on Regional Climate and its Impact on Population Health: A Comprehensive Study in Kolkata Metropolitan Region, India

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Abstract

Urban expansion affects land use and land cover changes in a particular region and influences regional climatic variability. Climate change poses a specific threat to coastal cities due to their geographical location and the people's livelihoods. This study aims to provide baseline input and scientific perspectives on urban expansion influences on regional climate and its impact on population health. The study used Satellite images to explore urban expansion, land cover change, and land surface temperature variation. The quantitative and qualitative data were collected through simple random sampling. The collected quantitative data were analyzed through descriptive statistics and logistic regression analysis, and qualitative data were analyzed through Narrative analysis. This study's findings provide important insights into urban expansion, the causes of regional climate change, and its impact on human health. The study result showed that vector-borne, waterborne, and air pollution-related diseases are the major threats to human health. In-depth interviews and Focus Group Discussions (FGD) revealed that most people stated that climate change directly and indirectly impacts their health. This study will help policymakers, urban planners, and healthcare providers to identify gaps in adaptation preparedness and allocate adaptation resources and strategic planning for climate change resilience.

Keywords: Urban expansion, Land-uses changes, Degradation of the natural environment, Climate change, Health problems, Kolkata Metropolitan Region.

Introduction

The urban area has grown increasingly large worldwide over the past 50 years(Crawley, 2008). Approximately half of the world's population now lives in cities and towns, as urban populations have grown steadily over the past few decades(Proust et al., 2012). In urban areas, interactions between human activities and environmental conditions contribute to climate change at the regional scale. In metropolitan areas, climate change is already evident at the micro-scale (Tayanç & Toros, 1997). The impacts of climate change are already evident in most cities worldwide, and they will continue to worsen in the coming years(He et al., 2019; Kirshen, Knee, & Ruth, 2008; Wilby & Perry, 2006). Due to the UHI effect, urban areas are likely to be more affected by climate change than adjacent rural areas(Chapman, Watson, Salazar, Thatcher, & McAlpine, 2017). Climate change is likely caused by the accumulation of greenhouse gases in the atmosphere that result from human activity (Boykoff, 2008; Hope, 2009). Climate change has been a pressing challenge of environmental challenges in Kolkata Metropolitan Region. In Kolkata, the population is growing rapidly, there is traffic congestion, air pollution, and traffic injuries are common. Land use and land cover changes can magnify the effects of extreme weather at the regional level and directly impact health. Land cover changes can sometimes exacerbate the effects of greenhouse gas-induced warming or even significantly impact local climatic conditions (Patz, Campbell-Lendrum, Holloway, & Foley, 2005). Human activities, such as transport and human mobility, are closely linked to air pollution in urban areas (Angelevska, Atanasova, & Andreevski, 2021). Local people live close to nature, gaining an intimate understanding of the environment over the time period (Manandhar, Pratoomchai, Ono, Kazama, & Komori, 2015). There are many climate-related hazards in the Kolkata region, including droughts, floods, heavy rains, strong winds, and heat waves. Daily environmental interactions and reliance on weather conditions determine local perceptions and knowledge of climate change (Laidler, 2006). Climate change takes place over a long period of time, such as decades. Climate change has become a focus of scientific, political, economic, and public debates in recent decades (Funatsu et al., 2019). The scientific evidence supporting the effects of weather, climate change, and climate variability on human health has grown substantially in

recent decades(Watts et al., 2021). In general, climate change has a detrimental effect on health due to rising temperatures, rising sea levels, and more extreme weather events(Haines & Ebi, 2019). Heat waves, floods, and droughts are just a few examples of extreme weather events that can directly affect health. As well as air pollution, poor water quality and lack of access to clean water, declining food security, the development of new disease-carrying vectors, and the changing distribution pattern of infectious diseases, health can be impacted indirectly(Haines & Ebi, 2019). Climate change is likely to increase health challenges between regions and among populations. The most vulnerable groups are children, pregnant women, the elderly, and people suffering from cardiovascular diseases, diabetes, lung disease, and mental illnesses. In addition, demographic, socioeconomic, and environmental factors can influence the size and pattern of risks. Climate change, directly and indirectly, affects human health. Climate change and regional environments comprise the prevalence and spread of infectious vector-borne diseases; Simentiounsly, it spreads water-borne diseases and general climate-sensitive health issues. This study advocated for such perspective, causes of regional climate change, and significant factors that's are directly associated with regional climate and identify the major health threats of the urban resident in Kolkata Metropolitan Region.

Study Area

The Kolkata Metropolitan Region's geographical location is in the eastern part of India state of West Bengal. This metropolitan economic zone is developing on the bank of the river Hooghly. This metropolitan region is India's third most populas metropolitan region after the Delhi and Mumbai metropolitan areas. This area is administrated by the Kolkata Metropolitan Development Authority(KMDA).Seasonal variation in temperature in the Kolkata region is more significant in the eastern part of the country. The highest temperature is recording the summer season, March to May, averaging 26- 37 degrees Celsius, and the rainy season starts from June to September. The average rainfall yearly is 1400mm to 1600 mm. this metropolitan region belongs to the tropical dry wet climate. Temperature and rainfall variation is shown in the study area from seasson to season. In the recent trend, the temperature is increasing over the period. In addition, selecting the Kolkata Metropolitan region from the low land of the Gangetic delta region and near the coast helps to account for potential perspectives on the link between climate change and climate change-related health risks.

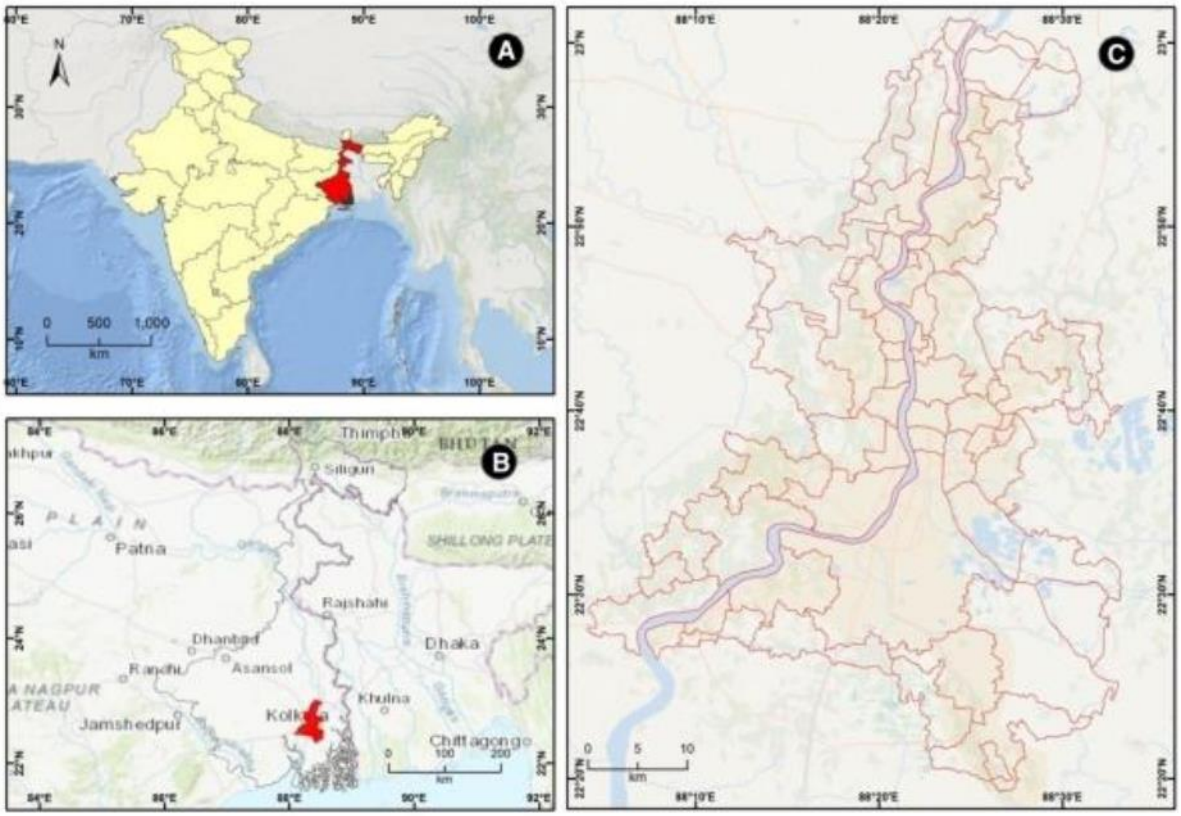

Fig.1.Location of study area:(A) Location of West Bengal in India, **(B)**Location of KMR in West Bengal and **(C)** Shows Kolkata Metropolitan Region.

Data and methodology

Satellite images have been used to explore the urban expansion, land use change, Normalized Difference Vegetation Index (NDVI) analysis and Land Surface Temperature (LST) variation of the Kolkata Metropolitan Region. This study has been carried out with the help of ARC GIS (10.51), ENVI 5.2 Software. Similarly**,** the cross-sectional study was conducted in Kolkata Metropolitan Region. The quantitative and qualitative method was used to address the differential facts of climate change and health problems in the Kolkata Metropolitan Region. In this study research ethics was maintained and participants gave their consent before starting the interviews. In this study used the multilevel cluster sampling technique to identify the urban unit and socio-economic status was the base level for selecting the cluster. The quantitative data were collected from the selected cluster through a simple random sampling method and qualitative data were collected from the selected cluster. In this study, the knowledge of climate change was assessed only by permanent residents, and the respondents age should be 45 and above. The

socio-demographic profile of the target population was depicted using descriptive statistics, Bi-variate analysis and logistic regression analysis and qualitative data were analysis through Narrative analysis.

Expected Findings

Trends of urban population in Kolkata Metropolitan Region

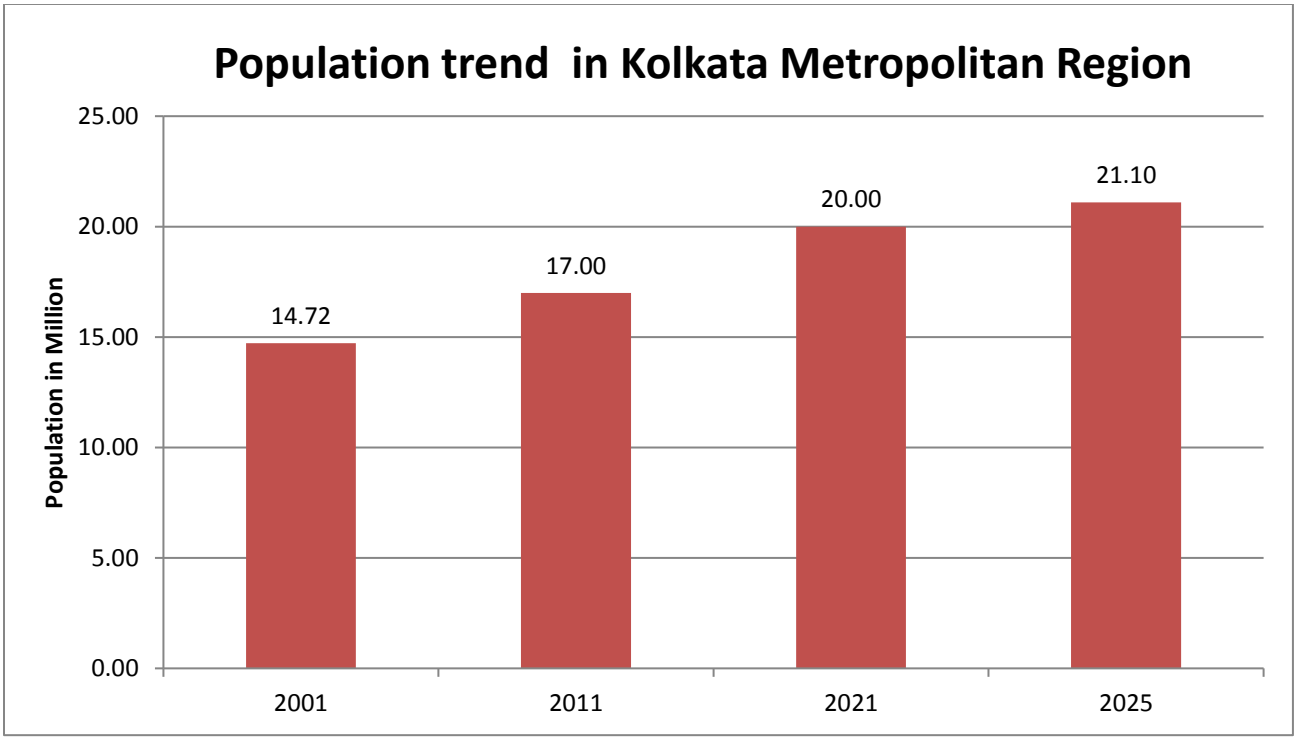

Figure. 2. Trends of urban population in Kolkata Metropolitan Region
Source: Census of India and Kolkata Metropolitan Development Authority documents

Figure 2 shows the Kolkata Metropolitan Region had a population of 14.72 million that in 2001. In the same way, it had become 20.0 million in 2021 while it was estimated that the urban population would become 21.10 million in 2025.

Urban expansion influences on regional climate

Urbanization is a complex phenomenon which necessarily includes the rapid conversion of rural area to an urban area in the process of development. Many rural counterparts have absorbed Kolkata Urban Agglomeration over the period due to urban expansion. Urban metropolitan area refers to a cluster of cities, towns, and outgrowths with at least one core mega-city surrounded by some small municipal units and administrative bodies. The issue of urban sprawl has become one of the most pressing challenges facing most cities today. Human activities such as urban expansion have a profound impact on our planet's climate despite covering a very small fraction of the Earth's land surface. There is a tendency to evaluate and characterize the urban sprawl exclusively based on some of the major socioeconomic indicators, such as population growth, commuting costs, employment shifts, and changes in city revenue. There are many metropolitan areas which are increasingly experiencing urban sprawl due to socioeconomic development under certain circumstances.

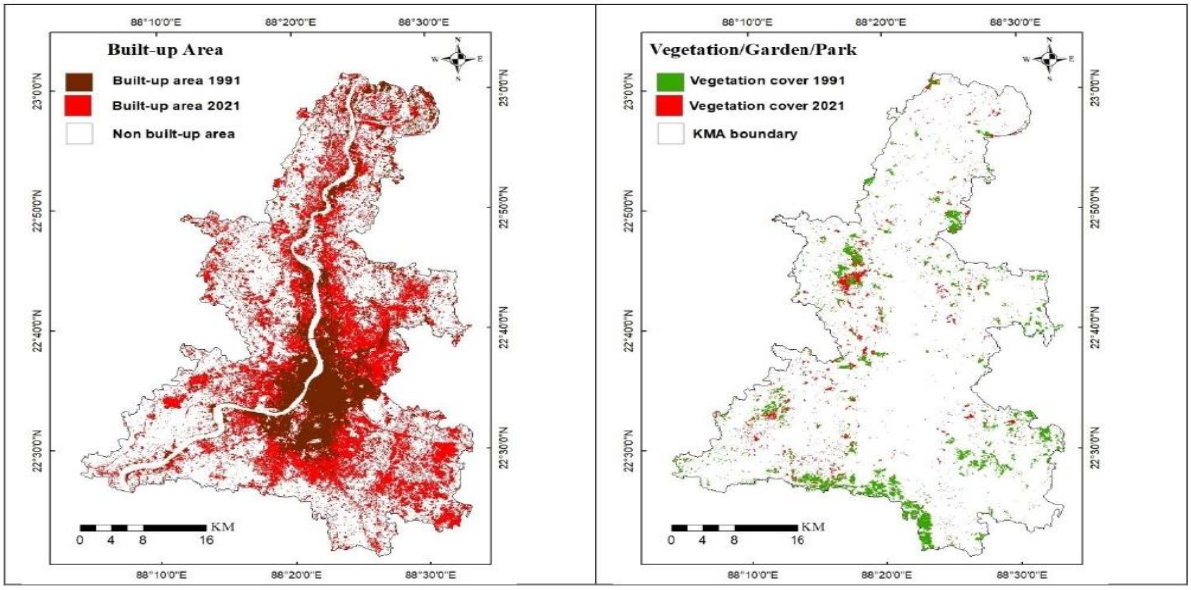

Figure. 3. urban expansion and declination of vegetation cover in the Kolkata metropolitan Region

In the last three decades, the urban growth and build up area has increased rapidly and subsequently, vegetation cover changed in the Kolkata Metropolitan Region. This Metropolitan Region consists of public and private infrastructure, and most of the settlements do not follow a

sustainable land use pattern. Uncontrolled urban expansion and land developments are crucial problems for the changing patterns of regional climate.

Land surface temperature variation and influence on the regional climate

(Figure.4) The Land Surface Temperature (LST) is an important variable within the Earth's climate system. Urban surface temperature depends upon the surface materials, vegetation cover, and solar radioactivity. In the recent time urban heat island is one of most important factor for urban climate. In this study, we observed urban core area surface temperature is more as compare to the surrounding rural areas of the city centre. In the city region, especially green spaces and industrial areas contributing towards urban heat island effect. In general, it occurs due to excessive concentration of concrete buildings, pavements, concrete road, and industry and factory zone. The temperature variation was observed in day and night time as well as winter and summer season. According to IMD, the highest temperature was recorded 43.5 degree Celsius in 2021 and the lowest temperature 10 degree Celsius in 2013. The results of the study shows the surface temperature varies from day by day and season to season to season. The average temperature of most of the areas was 31 degree Celsius and the highest temperature 41.07 degrees in 2021.

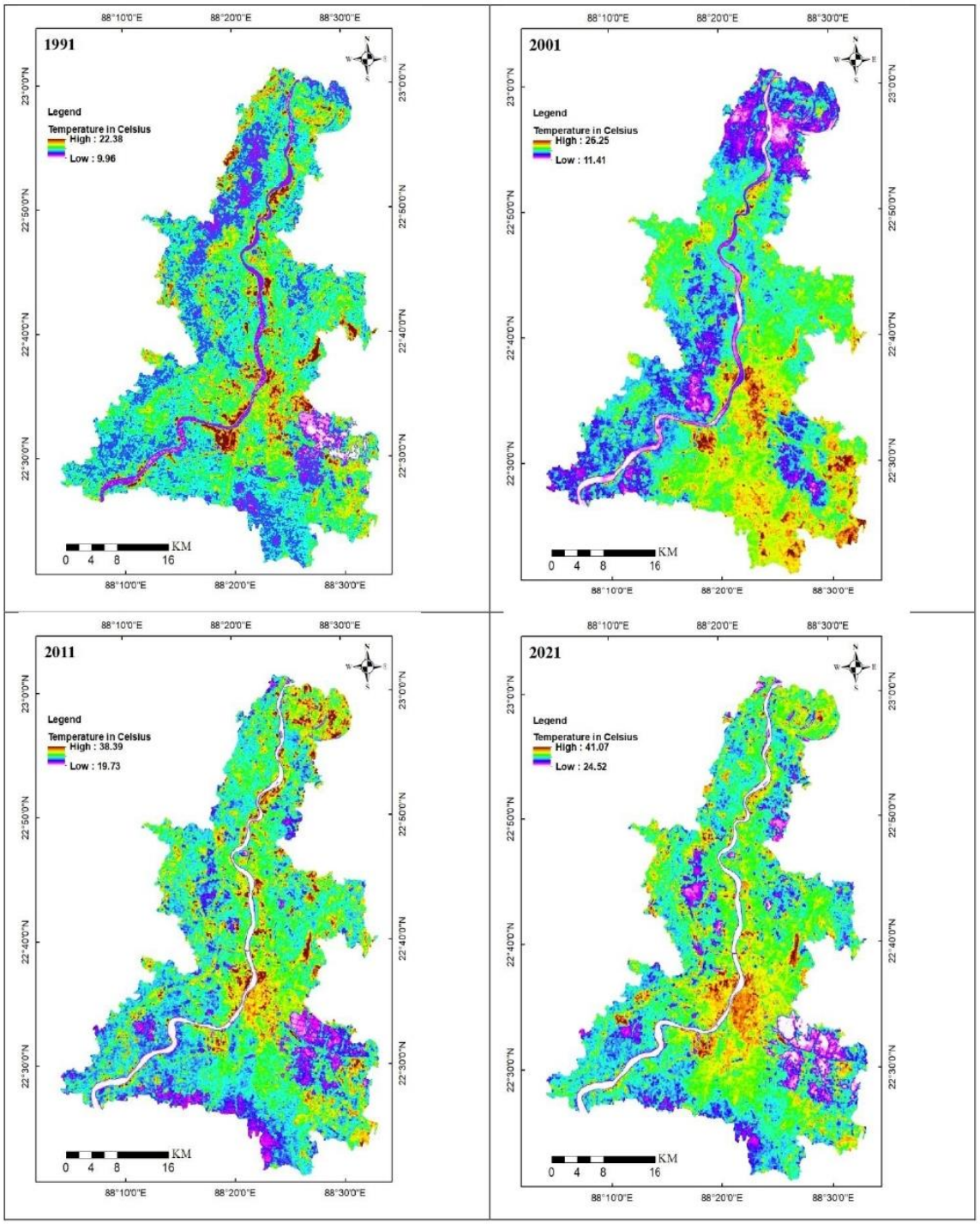

Figure. 4. Land Surface Temperature (LST) variation in Kolkata metropolitan Region from 1991-2021

Socio-economic status of the respondents

Table: 1 Prevalence of climate change effect on human health of the urban resident in Kolkata Metropolitan Region

Variables	No		Yes		Total	Chi-square P value
	N	%	N	%	Total	
Sex						
Female	76	32.6	157	67.4	233	0.020
Male	104	24.2	326	75.8	430	
Age (mean, SD)	64.72	9.22	55.81	7.22	663	0.000
Age groups						
45 to 54	29	10.8	240	89.2	269	
55 to 64	51	23.0	171	77.0	222	0.000
65 and above	100	58.1	72	41.9	172	
Marital status						
Married	133	23.2	440	76.8	573	0.000
Others	47	52.2	43	47.8	90	
Education						
Primary and below	155	55.2	126	44.8	281	0.000
secondary and above	25	6.5	357	93.5	382	
Occupation						
Govt. job	0	0.0	58	100	58	
private job	13	7.7	155	92.3	168	0.000
Business	42	25.3	124	74.7	166	
Others	125	46.1	146	53.9	271	
Religion						
Hindu	152	29.3	367	70.7	519	
Muslim	24	19.8	97	80.2	121	0.000
Christian	4	17.4	19	82.6	23	
Caste						

General	89	24.5	275	75.5	364	
SC/ST	50	39.4	77	60.6	127	0.003
Other Backward Classes	41	23.8	131	76.2	172	
Family type						
Joint	39	50.6	38	49.4	77	0.000
Nuclear	141	24.1	445	75.9	586	
Internet use						
No	87	59.2	60	40.8	147	0.000
Yes	93	18.0	423	82.0	516	
Monthly income (mean, SD)	26417	5557	29636	6141	663	0.000

Table 2 shows the multivariate association between socio-demographic variables and climate change linked with the health problems in Kolkata Metropolitan Region. Study results showed that the socio-demographic variables of education, internet use and monthly income are found statistically significant (P<0.05) with the dependent variable of climate change linked with the health problems.

Table 2 Multivariate association between socio-demographic variables and climate change effects on human of the urban residents in Kolkata Metropolitan Region

Variables	**UOR**	**95% CI**		**P value**	**AOR**	**95% CI**		**P value**
Sex								
Female	1	1			1	1		
Male	1.52	1.07	2.16	0.020	1.13	0.69	1.83	0.628
Age group								
45 to 54	1	1			1	1		
55 to 64	0.405	0.25	0.665	0.000	0.68	0.37	1.24	0.210
65 and above	0.087	0.05	0.142	0.000	0.46	0.22	0.97	0.041
Marital status								
Others	1	1			1	1		

Married	3.62	2.29	5.71	0.000	0.83	0.43	1.60	0.574
Education								
Primary and below	1		1		1		1	
Secondary and above	17.57	10.99	28.07	0.000	10.67	6.068	18.77	0.000
Religion								
Hindu	1		1		1		1	
Muslim	1.67	1.03	2.72	0.037	2.63	1.25	5.55	0.011
Christian	1.97	0.66	5.88	0.226	2.67	0.63	11.27	0.181
Caste								
General	1		1		1		1	
SC/ST	0.50	0.32	0.77	0.001	0.35	0.20	0.64	0.001
Other Backward Classes	1.03	0.68	1.58	0.877	0.80	0.42	1.54	0.515
Family type								
Joint	1		1		1		1	
Nuclear	3.24	1.99	5.26	0.000	1.39	0.73	2.63	0.317
Internet use								
No	1		1		1		1	
Yes	6.60	4.43	9.82	0.000	1.89	1.05	3.41	0.034
Monthly income	1.00	1.00	1.00	0.000	1.00	1.00	1.00	0.000

UOR Unadjusted Odds Ratio**, AOR** Adjusted Odds Ratio**.**

Results from logistic regression analysis showed that respondents who have secondary and above education (AOR 10.67, 95% CI: 6.07-18.77) are more likely to perceive knowledge about climate change-related health problems than respondents with primary education and below. And Schedule caste and schedule tribe respondents (AOR 0.35, 95% CI: 0.20-0.64) have less knowledge about the climate change related health problems than the general caste respondents. Similarly, internet user respondents (AOR 1.89, 95% CI: 1.05-3.41) are more likely to have knowledge about climate change related health problems as comparatively non-internet user respondents in the Kolkata Metropolitan Region **(Table 2)**.

Table: 3 Climate change related major health problems of the urban residents in Kolkata Metropolitan Region

	Climate change effects on the health		
Heath problems	Mild	Moderate	Severe
Temperature related illness	285(48.99)	255(38.46)	**123 (18.55)**
Vector borne disease	218(32.88)	167(25.19)	**278(41.93)**
Water and food borne disease	155(23.38)	288(43.44)	**220(33.18)**
Depression and anxiety and others	197(29.71)	238(35.9)	228(34,39)
Respiratory disease/Asthma	97(14.63)	196(29.56)	**370(55.81)**
Allergy/ Skin disease	295(44.49)	153(23.08)	215(32.43)
Could and cough	94(14.18)	278(41.93)	**291(43.89)**
Heat stroke/Sun stroke	132(19.91)	404(60.64)	127(19.16)
Extreme weather related health effects	339(51.13)	254(38.31)	70(10.56)

The respondents reported that, **vector-borne diseases**, **waterborne diseases**, pollution-related diseases are the major health threats in the Kolkata Metropolitan Region.

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