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Trends in Climatic Variables and Pattern of Diseases: A study in South Assam of the Eastern Himalayan region

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Abstract: Assessing the impact of climate change is crucial for identifying changes that have already taken place, which will lead to future predictions. A trend analysis of two important weather variables, mainly rainfall and temperature for South Assam, shows rising trends of the weather variables indicating climate change. The findings focus on the prevalence of diseases associated with climate change in the southern region of Assam. The trend analysis of the weather variables is done with the help of Sen's slope estimator and Mann Kendall statistic. The sample data is also used to assess the effects of weather variables connected to the climate on health. The analysis indicated occurrences of climate induced diseases in the study area with wide variations across districts and rural-urban areas.

Keywords: climate change • diseases • health variables • sen's slope estimator • trend analysis • weather variables

Introduction

Climate Change studies have been carried in recent years to identify possible climate trends and changes at the global level. These studies have largely summarised that a growing trend of surface temperature is present in India. It has been suggested from the findings that India's trend and magnitude of warming in recent years is broadly consistent with global trends and intensities. However, due to the comparatively large increase in maximum daily temperature over a significant part of India, there is a relatively different diurnal temperature range trend than those observed in other parts of the world. Comparably, numerous researches pertaining to the alteration of the rainfall pattern in India has revealed the absence of a distinct pattern of average rainfall throughout the nation, despite the fact that there is significant evidence that the rainfall trend is declining in the majority of the biosphere (Mooley and Parthasarathy 1984). Human beings are intimately interconnected to the Earth's physical, geological and biological cycles. Any fundamental global change affecting these systems would have a devastating effect on human health in different ways. As one of the abiotic factors in the environment that surrounds us, climate parameters have an important influence. As a result, any alteration in the characteristics of the climate will affect people, either directly or indirectly. In the third assessment report of the United Nations's IPCC (2001), it has been observed that the threat to human health is projected to increase with climate change. The health implications of climate change can be both direct and indirect, primarily resulting from changing disease vector ranges, air and water quality, etc. Therefore, on-going efforts in the protection of human health are challenged by a more recent challenge of global climate change.

Review of Literature

Studies on climate change concentrated on the trends of climatic variables across different regions in the globe and tried to strengthen methodologies for assessment over the period of time. Wilkinson and Marmot (2003) compiled some techniques for monitoring the climate change related effects on health. The authors, moreover, gave emphasis that climate change is a gradual process and can only be detected decades into the future. As a result, the effects of these changes on health have grown slowly. In the long run, there are large roles played by further confounding factors. Thus, monitoring studies should be designed to allow for the analysis of confounding effects or in a setup where those effects can be minimised.

Roy et al. (2020) observed a study based on the seasonal and annual rainfall in Northeastern region of India to look into the trends of rainfall over a long period of time using Sen's Slope estimator. Trajakovich and Kolkovic (2009) mentioned that though there has been change in climatic condition throughout the world but there was no uniformity in its impact across the regions.

Also, there has been various studies that relates to the pattern of change of rainfall in India which observed that the average rainfall in the country has no clear trend of increasing and decreasing (Mooley Parthasarathy, 1984; Thapliyal and Kulshrestha, 1991; Kumar et al., 2010) Astrom et al. (2012) provided in their study an analysis that the number of people vulnerable to the effect of dengue would increase by approximately 0.28 billion by 2050 as projected at the current trend of climate change globally and GDP per capita remained constant. Nevertheless, in 2050, the estimated loss of around 0.12 billion people of dengue would occur in the world. Consequently, climate and socio-economic factors play a very important character in the geographical distribution of dengue.

Asad et al. (2015) in their study documented hazards, impact of hazards and coping strategies in three villages of the Chitral district of Khyber Pakhtunkhwa province in Pakistan. The study provided information on the types, frequency, and damage that are caused by hazards. According to the study, a change in the climate has led to a rise in unpredictable and growing hydro-meteorological hazards. The data also shows that hazards have caused major damage to infrastructure, crops and agricultural land. Flash floods and avalanches are among the major hazards. Temporary relocation to other villages, borrowing money to repair damaged infrastructure and relying on local village organisations and volunteers to help in emergency are the coping strategies.

Nwoke et al. (2009) in their reviewed paper about effect of climate on health observed that the effect of human actuated environmental change are seen to bargain the supportability of human advancement as it consists of natural emotionally supportive networks. Also WHO (2009) in their report mentioned about preventing and protecting health from climate change.

The report prepared by the U.S. Global Change Research Program (2016) on the climate change related effects on human health in the United States has the main objective to give a detailed, evaluative and quantitative calculation of the projected and observed health effects in the United States resulting due to climate change. In the study, assessment was initiated to make the government health officials, town and planners of disaster and various representatives of government and also from outside that are interested in understanding the risks that climate change provides to human health. The literature on the outcomes of health and its exposures related to climate change is highlighted in the report. The study gives particular emphasis to research presented from 2007 through 2015 that quantifies the existing or future climate change related effects on health and determines risk factors related to them and identifies the higher risk populations in different sections of the report, viz, temperature-related illness and death, air pollution impacts and diseases due to vectors and water.

Based on the review of studies, it is observed that while numerous studies have been conducted on the effects of climate change on human health throughout the nation, none have been specifically conducted for Assam or the Northeastern states in the Eastern Himalaya.

The topography and physiography of the Northeastern region differs completely from other regions of the world.

The present study is conducted in the South Assam, consisting of four districts of the Eastern Himalayan region. The main objective, here, is to examine the pattern of climatic variables mainly rainfall and temperature for a long period. An attempt has been made to determine the pattern of diseases in the study area and if there is any linkage with the environmental factors associated with the diseases.

Profile of the Study Area

Assam, a prominent state in India's Northeastern region, boasts a population of 31.2 million as per 2011 census, contributing significantly to the region's total population of 45.4 million. Southern Assam comprises Cachar, Karimganj, Hailakandi, and Dima Hasao districts, experiencing tropical wet and monsoon climates, with high temperatures throughout the year. Rainfall, exceeding 78 cm annually, occurs mainly from May to November, fostering lush vegetation and diverse animal species in the tropical wet forests. Barak Valley, consisting of Cachar, Hailakandi, and Karimganj districts, was historically part of the Surma Valley. Dima Hasao, a hill district, is governed under the sixth schedule of the Indian constitution. With a population of 38.36 lakhs in 2011, South Assam encompasses rich biodiversity and unique cultural heritage within its varied landscapes.

Database and Methodology

Data: The study is based on both primary and secondary data. The data on district wise climate variables are obtained from the Statistical Handbook published by the Directorate of Economics & Statistics and by the India Meteorological Department (IMD). District wise monthly data of rainfall has been collected for the four districts of South Assam for the period 1990-2019. On the other hand, district-wise seasonal and annual minimum and maximum data of temperature has been collected for the four districts of South Assam for the period 1901-2002. A field survey was carried out in each of South Assam's four districts provided the data at the household level. To gather sample data for the study, 367 households were chosen from four villages and four urban wards in South Assam covering Cachar, Karimganj, Hailakandi and Dima Hasao districts by using a random sampling method.

Statistical Tools Used: Non-parametric methods, namely Mann-Kendall (M-K) test, is the best method out of all the methods considered for analysis of trends that is preferred by various researchers. Among the various statistical trend analysis techniques, Mann-Kendall (M-K) Test and Sen's Slope estimator were used in the study to evaluate and analyse the problem. The M-K test is mainly a non-parametric rank based test that checks the null hypothesis, which has no trend against the alternative hypothesis having either an increasing or decreasing trend. In this test, a very high and positive value of S indicates an increasing trend and a very low and negative value of S indicates a decreasing trend.

In case of large samples with N>30, the following mean and variance is used in order to conduct the test using a normal distribution:

$$E[S] = 0$$

$$\mathrm{Var}(S) = \frac{N(N-1)(2N+5) - \sum_{k=1}^{n} t_k(t_k-1)(2t_k+5)}{18}$$

Here, n = number of tied groups, tk = number of data points in the kth tied group. The Z-statistic (standard normal deviate) is calculated as follows:

$$Z = \begin{cases} \dfrac{S-1}{\sqrt{\mathrm{Var}(S)}} & \text{if} \quad S > 0 \\ 0 & \text{if} \quad S = 0 \\ \dfrac{S+1}{\sqrt{\mathrm{Var}(S)}} & \text{if} \quad S < 0 \end{cases}$$

Here, the null hypothesis (H0) is rejected, if the computed value of $|Z|>Z\alpha/2$ at α level of significance in a two-sided test and H0 is accepted, if $|Z|<Z\alpha/2$ at the same level of

significance. In this analysis, H0 is tested at 95% confidence level.

Results and Discussion

The result of the trend analysis of rainfall data for the period 1990-2019 as available from the IMD for different stations across districts of south Assam has been analysed using Sen's estimator of slope is reported in Table 1. It is observed that the rainfall trend shows huge variability in magnitude and direction of trend from one district to another. Here, 48 values (12 months each from 4 districts) of Sen's coefficient for all districts of South Assam have been estimated. The analysis reveals that 34 values of Sen's coefficients are negative, 14 values are positive and there are no values which are zero (Table 1). Out of these 34 negative values, 9 of them were statistically significant at 95% level of significance and 2 positive values were found to be statistically significant. This indicates that the decreasing trend of rainfall is mainly dominating the situation. Hailakandi and Dima Hasao are the districts where the trend of rainfall is negative for most months and Cachar and Karimganj have experienced an increasing trend of rainfall for 6 months and a decreasing trend for 6 months.

Table 1. Sen's Estimator of Slope (mm/year) for Monthly Rainfall in South Assam during 1990-2019

Months	Cachar	Karimganj	Hailakandi	Dima Hasao
January	-0.02	-0.01	**-0.03**	-0.01
February	**-1.09**	**-0.28**	**-0.28**	-0.28
March	-0.04	-0.93	**-1.89**	**-0.04**
April	-0.21	0.33	-1.14	-2.25
May	0.89	0.89	0.89	-4.73
June	**3.35**	4.07	-1.72	-8.56
July	**2.80**	1.27	-2.73	-3.51
August	0.34	0.06	-1.14	-7.94
September	0.50	-0.52	**-2.00**	**-0.61**
October	0.78	0.11	-0.58	0.11
November	-0.05	-0.01	-0.09	-0.01
December	-0.02	-0.13	-0.09	**-0.04**

Note:1. Statistical significance at 95% confidence level as per the Mann–Kendall test (+ for increasing and − for decreasing) is highlighted by bold values. *Source.: Computed by authors.*

The result of the trend analysis of rainfall data for the period 1901-2002 as available from the IMD for different stations across districts of south Assam has been analysed using Sen's estimator of slope is reported in Table 2.

Table 2. Sen's Estimator of Slope (mm/year) for Seasonal Maximum Temperature in South Assam during for the period 1901-2002

District	Winter	Pre monsoon	South-west monsoon	Post monsoon
Cachar	0.001	0.004	0.004	0.008
Karimganj	0.003	0.003	**0.004**	0.008
Hailakandi	0.004	0.003	0.004	0.008
Dima Hasao	**0.005**	**0.006**	0.005	0.008

Note: 2. Statistical significance at 95% confidence level as per the Mann–Kendall test (+ for increasing and − for decreasing) is highlighted by bold values.
Source-: Computed by authors

In Table 2, the seasonal maximum temperature trend for the four districts of South Assam is reported. 16 values (4 months each 4 districts) of Sen's coefficient for all the districts of South Assam have been estimated. It is revealed that all the 16 values of Sen's coefficients are positive. This clearly indicates that the increasing trend of maximum temperature is dominating in the four districts of South Assam. Out of the 16 positive values, 3 values are statistically significant at 95% level of significance. For Dima Hasao district, the trend of maximum temperature is found significant for two seasons and in Karimganj district the trend is significant for one season.

In Table 3, the seasonal minimum temperature trend for the four districts of South Assam has been given. 16 values (4 months each 4 districts) of Sen's coefficient for all the districts of South Assam have been estimated. It is revealed that all the 16 values of Sen's coefficients are positive; no values are negative or zero. This clearly indicates that the increasing trend of minimum temperature is dominating in South Assam. Out of the 16 positive values, 14 values are statistically significant at 95% level of significance and remaining 2 positive values are not significant. Dima Hasao and Hailakandi are the districts for which the trend of minimum temperature is significant for all seasons compared to the other two districts.

Table 3. Sen's Estimator of Slope (mm/year) for Seasonal Minimum Temperature in South Assam during 1901-2002

District	Winter	Pre monsoon	South-west monsoon	Post monsoon
Cachar	**0.006**	**0.004**	0.001	**0.009**
Karimganj	**0.005**	**0.004**	0.001	**0.009**
Hailakandi	**0.006**	**0.004**	**0.002**	**0.009**
Dima Hasao	**0.007**	**0.005**	**0.002**	**0.008**

Note: 3. Statistical significance at 95% confidence level as per the Mann–Kendall test (+ for increasing and − for decreasing) is highlighted by bold values. *Source- Computed by authors.*

The trend analysis of annual maximum temperature for the four districts of South Assam is reported in Table 4. It is revealed that all the 4 values of Sen's coefficients are positive. This clearly indicates that the increasing trend of maximum temperature is dominating in the districts of South Assam. Here, of the overall 4 positive values, 1 value is statistically significant at 95% level of significance. Karimganj is the district for which the trend of annual maximum temperature is significant.

Table 4. Sen's Estimator of Slope (mm/year) for Annual Maximum Temperature in South Assam during 1901-2002

Districts	Sen's Coefficient
Cachar	0.001
Karimganj	**0.001**
Hailakandi	0.001
Dima Hasao	0.002

Note: 4. Statistical significance at 95% confidence level as per the Mann–Kendall test (+ for increasing and − for decreasing) is highlighted by bold values. *Source- Computed by authors.*

In Table 5, the trend of the Minimum Annual Temperature for the four districts of South Assam is reported. The analysis shows that all the 4 values of Sen's coefficients are positive. This clearly indicates that the increasing trend of minimum temperature is dominating in the four districts of South Assam. Of the overall 4 positive values, all the values are statistically significant at 95% level of significance. Thus, the trend of annual minimum temperature is significant for all the four districts, i.e., Cachar, Karimganj, Hailakandi and Dima Hasao.

Table 5. Sen's Estimator of Slope (mm/year) for Annual Minimum Temperature in South Assam during 1901-2002

Districts	Sen's Coefficient
Cachar	**0.001**
Karimganj	**0.001**
Hailakandi	**0.001**
Dima Hasao	**0.002**

Note: 5. Statistical significance at 95% confidence level as per the Mann–Kendall test (+ for increasing and − for decreasing) is highlighted by bold values. *Source- Computed by authors.*

The Diseases related to Climate Change in South Assam

The health outcomes related to climate change, as identified by WHO, are extreme weather related illnesses & death, heat-related illness, respiratory illness, water-borne diseases, vector-borne diseases, nutritional & food-borne diseases, non – communicable diseases, mental & psychological health diseases, etc. Moreover, in the report by the U.S. Global Change Research Programme, 2016 "The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment", it is mentioned that there are seven different types of health threats which include- (i) Food borne illness and nutrition (Norovirus infection or salmonellosis), (ii) Health impacts of air quality (respiratory impacts which includes asthma, respiratory allergies and airway diseases and Cardiovascular related diseases which includes hypertension, heart attack, stroke etc), (iii) Health impacts of extreme weather events (hurricanes and coastal storm related injury, lung diseases due to mould exposure, virus and bacterial infections due to flood events and sea level rise etc), (iv) Mental health & wellbeing (eco-anxiety, depression, suicidality, sleep disorder, social avoidance, irritability etc), (v) Temperature related illness and death (cardiovascular disease, cerebrovascular disease, respiratory disease and diabetes related conditions), (vi) Vector-borne diseases (dengue, malaria, chikungunya, yellow fever, zika from mosquitoes, lyme disease from ticks, plague from fleas, and schistosomiasis from aquatic snails) and (vii) Water related illness (diarrhoea, dysentery, typhoid- fever) .

From the sample survey of 367 households from four districts of south Assam, the pattern of diseases suffered by the respondents has been identified. Out of the various diseases related to climate change, the following diseases are identified to be suffered by the respondents in South Assam. These are- temperature related illness and death (cardiovascular diseases, respiratory and renal diseases, heat related illness), extreme weather related illness and death (injuries and fatalities), air pollution related health effect (respiratory allergies, asthma and cardiovascular diseases), water & food-borne diseases (malnutrition, diarrheal diseases, cholera), vector-borne diseases (malaria, dengue, chikungunya, encephalitis), infectious diseases (tuberculosis and Covid-19) and mental, nutrition and other health effects (anxiety, depression, sleep disorder, social avoidance, salmonellosis).

The percentage of disease related to climate change occurring in the four districts of South Assam is reported in Table 6. Out of the 367 households in South Assam, 43.15 per cent of respondents suffered temperature related illness & death with wide variations among the districts. In the Cachar district, 42.11 per cent suffered from the disease followed by 60.98 per cent in Hailakandi, 42.57 per cent in Karimganj and 26.92 per cent in Dima Hasao. Extreme weather related illness & death sufferers in the south Assam consisted of 4.78 per cent with no such cases in Hailakandi district, 2.63 per cent in Cachar, 8.78 per cent in Karimganj and 7.69 per cent in Dima Hasao. Air pollution related health effect sufferers in the south Assam consisted of 48.51 per cent with the highest incidences of 68.29 per cent in Hailakandi district, 46.05 per cent of the households in Cachar, 41.22 per cent households in Karimganj and 38.46 per cent in Dima Hasao. There is presence of water & food-borne diseases in the south Assam to the extent of 46.70 per cent of respondents with 54.61 per cent of the households in Cachar, 36.49 per cent in Karimganj, 34.15 per cent in Hailakandi and 61.54 per cent in Dima Hasao. Vector borne disease was present in 36.99 per cent of respondents' households in the south Assam with variations in Cachar district to the extent of 53.29 per cent households, 40.54 per cent in Karimganj, 19.51 per cent in Hailakandi and 34.62 per cent in Dima Hasao. Infectious disease, on the other hand, is present in 29.56 per cent in south Assam with 26.32 per cent households in Cachar, 18.92 per cent in Karimganj, 26.83 per cent in Hailakandi and 46.15 per cent in Dima Hasao. Mental, nutrition and other health effects sufferers in south Assam consisted of 4.48 per cent of sample respondents. There is no evidence of mental, nutrition and other health effects found in Hailakandi and Dima Hasao, but it is present in 11.84 per cent of households in Cachar and 6.08 per cent households in Karimganj. Thus, here, we can see that out of the 7 mentioned diseases, Cachar has more cases of water & food-borne diseases, vector borne disease and temperature related illness & death and least cases of extreme weather related illness & death. For Karimganj, there are more cases of temperature related illness & death and the fewest cases of mental, nutrition & other health effects.

Table 6. Percentage of sample respondents suffered by Diseases related to Climate Change across the four districts of South Assam

Diseases	Cachar	Karimganj	Hailakandi	Dima Hasao	South Assam total
Temperature Related Illness & Death	42.11	42.57	60.98	26.92	43.15
Extreme Weather Related Illness & Death	2.63	8.78	0.00	7.69	4.78
Air Pollution Related Health Effect	46.05	41.22	68.29	38.46	48.51
Water & Food Borne Disease	54.61	36.49	34.15	61.54	46.70
Vector Borne Disease	53.29	40.54	19.51	34.62	36.99
Infectious Disease	26.32	18.92	26.83	46.15	29.56
Mental, Nutrition & Other Health Effects	11.84	6.08	0.00	0.00	4.48

Source: Computed by authors.

In Hailakandi, there are highest percentage of cases of air pollution related effect on health and temperature related illness & death out of the four districts and no cases of extreme weather related illness & death and mental, nutrition & other health effects. In Dima Hasao, there is the highest percentage of cases of water & food borne disease and no cases of mental, nutrition and other health effects.

In Table 7, the percentages of diseases related to climate change in rural and urban areas of South Assam are presented. Here, out of the total 151 households surveyed in rural areas of the four districts of South Assam, 37.75 per cent of households have temperature related illness & death, 5.96 per cent households have extreme weather related illness & death, 45.70 per cent households have air pollution related health effect, 32.45 per cent of the households have water & food borne disease, 24.50 per cent of the households have vector borne disease, 21.19 per cent have infectious disease and 4.64 per cent of the households have mental, nutrition & other health effects. On the other hand, out of the 216 households taken in the urban areas of the four districts of South Assam, 47.22 per cent of the households have temperature related illness & death, 4.63 per cent households have extreme weather related illness & death, 46.30 per cent households have air pollution related health effect, 54.63 per cent of the households have water & food borne disease, 56.02 per cent of the households have vector borne disease, 27.31 per cent have infectious disease and 9.26 per cent of the households have mental, nutrition & other health effects. Thus, we can see that, in rural areas, there is the highest percentage of cases of health effects related to air pollution and there is least percentage of cases of mental, nutrition & other health effects. Whereas, in urban areas, there are most cases of vector borne disease and the least percentage of cases of extreme weather related illness & death. However, a total 24.6 per cent household suffered from the diseases related to climate change in rural areas and that of 35.05 per cent in urban areas. Thus incidences of climate change induced diseases are higher in towns than in villages of south Assam.

Table 7. Percentage of Disease suffered by Sample respondents related to Climate Change in Rural and Urban areas of South Assam

Diseases	**Rural**	**Urban**
Temperature Related Illness & Death	37.75	47.22
Extreme Weather Related Illness & Death	5.96	4.63
Air Pollution Related Health Effect	45.70	46.30
Water & Food Borne Disease	32.45	54.63
Vector Borne Disease	24.50	56.02
Infectious Disease	21.19	27.31
Mental, Nutrition & Other Health Effects	4.64	9.26
Average	24.60	35.05

Source: Computed by authors.

Conclusion

Due to the increasing impact of climate change, it has become imperative to analyse the patterns of health issues. Moreover, it is important to take into account the pathways to climate change induced diseases, the implications and policy framework. South Assam in the Eastern Himalayan region is mainly characterised by moderate climate throughout the year with tropical humid weather, thus, making it a region in which special focus should be given regarding the health risks associated with such climate change. From the analysis, it is observed that climate change resulted in wide fluctuation in rainfall and temperature in the south Assam. Out of the four districts of south Assam in the Cachar district, all the diseases identified are present. It has a number of cases of water & food borne disease and also vector borne disease. So, focus should be given to water purification, food hygiene inspection, sanitation and use of mosquito and vector control. Karimganj and Hailakandi, on the other hand, are the districts in which a number of cases of temperature related illness & death and air pollution related health effects are there, so measures should be taken in providing fresh air through control of air pollution and also through plantation of trees. Dima Hasao has more cases of water & food borne disease like Cachar and then there are also a good number of cases of infectious disease and air pollution related health effects. Measures such as maintaining water and food hygiene and also maintaining proper sanitation should be given priority.

It is to be noted that the risks associated with the weather variables and climate change also involve the risks that will result in the effective adaptation options which remain unidentified and not implemented, giving rise to preventable illnesses and increases costs. A cost-saving and cost-effective technique should be adapted to for diminishing climate change related issues for sustainable livelihood. The priority and focus should be on adaptation strategies to improve the quality of health irrespective of the changes in climate. In fact, adaptation to the various measures might not be an expensive concern. Assessment and implementation of the suitable policies should be focused and it should be helpful to the decision makers to select options related to adaptations for reducing the impacts which are negative.

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