Volume 3, Issue 1, January 2017

ISSN NO: 2454 - 9827

North Asian International Research Journal Consortium

North Asian International Research Journal of Social Science & Humanities

IRJIF IMPACT FACTOR: 3.015

NAIRJC JOURNAL PUBLICATION

North Asian International Research Journal Consortium

Welcome to NAIRJC

ISSN NO: 2454 - 9827

North Asian International Research Journal Social Science and Humanities is a research journal, published monthly in English, Hindi, Urdu all research papers submitted to the journal will be double-blind peer reviewed referred by members of the editorial board. Readers will include investigator in Universities, Research Institutes Government and Industry with research interest in the general subjects

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ECONOMETRIC ANALYSIS OF URBANIZATION AND CLIMATE CHANGE IN NORTH-EAST INDIA

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ABSTRACT

Changes in land use with rapid urbanization have important anthropogenic influences on our climate. While urbanization is one of the important ingredients of development, its negative effects on the environment is not simply ignorable. Its impact on climate change is one of the rising concerns of today's society and several studies have been raising this issue. However, less attention has been paid to study this impact on the climate of North-East India. The paper studies the pattern of climate change in the North-East part of India and its relationship with the urbanization of this region. One major advantage of studying the relationship of urbanization and climate change in the North-East India is that it is one of the least industrialized parts of the country. Therefore the impact of urbanization is more relevant and perspicuous. The rapid urbanization in the seventh and eighth decades of the twentieth century has its impact on the climate of this region, which is visible after one or more decades. The various econometric tests and analyses provide evidences regarding the impact of urbanisation on the climate factors of this region. The rising temperature and unseasonal rainfall even with little industrialization is a matter of concern for this region. Though the size of the urban population is less than 30 percent in most of the states of the North-East India except Manipur and Mizoram, further urbanization and any industrial development may lead to serious environmental concerns in the region.

***Key words:* Urbanization, climate, rainfall, temperature, regression**

1. INTRODUCTION

Urbanization is a dynamic process through which structure of the population lived in urban areas changes and a change always has some impacts. Studies like Uttara et al. (2012) and Wen-zhang et al. (2014) have mentioned certain specific features which are closely related to urbanisation, of course not in strict sense, such as industrialization, modernization, globalization, changed social behaviour etc. All these human induced processes related with the urbanization have direct or indirect effects on our environment including climate change. The *Climate Change 2014: Synthesis Report* (IPCC, 2014)confirms a clear and increasing human influence on the climate structure: "*the more human activities disrupt the climate, the greater the risks of severe, pervasive and irreversible impacts for people and ecosystems, and long-lasting changes in all components of the climate system*" (IPCC, 2014).Generally, in urban places the intervention of human activities on the natural environment is the most intense and the change in the natural environment is greatest. Urbanisation leads to increase in consumption of natural resources and raises the demands for more energy which affects the climate in a very prominent way (Wen-zhang et al., 2014).

There are several studies related to the impact of urbanization on the local and global climate. Wen-zhang et al. (2014) have studied the variation of urbanization in the Changzhou city of China during 1952-2011and its impaction the local climate of Changzhou analyzing the characteristics of climatic factors such as annual temperature, wind, precipitation, solar radiation and so on. They revealed preliminarily that there are increasing trends over the time in the annual mean temperature, min-mean temperature and max-mean temperature. In general, the trends are gradually rising. Similarly Uttara et al. (2012) have studied the impact of urbanization on the climate of India and have found that a rise in urbanization after 1900s has created various socio-economic and environmental problems in India.

India is among one of the rapidly developing Asian countries. In the past four decades, India's urban population has increased with an expanding city scale. In 2010, the share of urban population was about 31 percentage of the total population. Statistics has shown that from 1970s, the decadal growth rate of the level of urbanization is36.5% in India (World Bank, 2013). Due to rapid urbanization in India, environmental degradation has been occurring very rapidly and causing many problems like shortages of housing, worsening water quality, excessive air pollution, noise, dust and heat, and the problems of disposal of solid wastes and hazardous wastes (Uttara et al., 2012). Urbanization which has become a trend of the development in the country has multiple effects on the climate.

Though there are studies on the impact of urbanisation on the climate of India, less attention has been paid to study this impact on the climate of North-East India. North-East Region (NER) of India is among one of the areas in the country where industrialization is very less (almost nil). Therefore, one can find some direct effects of urbanisation on the climate of this region more lucidly. In North-East India, which is one of the least industrialized parts of the country, the impact of urbanization should be more relevant and perspicuous. The paper attempts to explore and examine the climate changes of the NER and its possible relation with the urbanisation of this region. The paper is structured in five sections. Introduction is followed by the section 2 of methodology and data sources. Section 3 deals with the analysis and discussions based on the data including the relationship of urbanisation and local climate change. Section 4 provides an econometric analysis of the data determining the impacts of urbanisation on the climate change through various econometric tools. Finally section 5 concludes as empirical evidence.

2. DATA AND METHODS

2.1. Study area

The north-eastern region (NER) of India is located in the eastern part of the Himalayas with perennially humid climate, adequate rainfalls and six distinct seasons. Having over 60% of the crop area under rain-fed agriculture, this region is highly vulnerable to climate change. The region has a diverse geography with two main river basins (the Brahmaputra and Barak), mountains, hills, plains and lakes. Therefore, the region has an experience of diverse climatic conditions.

2.2. Data

This paper has analysed the yearly data (1901-2010) of minimum temperature, maximum temperature and rainfall collected from the: Indian Institute of Tropical Meteorology (An Autonomous Body under the Ministry of Earth Sciences, Govt. of India)which is available at:ftp://www.tropmet.res.in/pub/data/txtn/NEW-TXREGION.TXT.In this study urbanization is referred to the changes of urban population in NER. The data for the urbanisation is in the form of 'percentage of urban population to the total population' and is based on the various Censuses in India. Census data are the source of urbanisation in this study.

2.3. Methods

The annual and decadal averages of the values of the climatic factors (minimum temperature, maximum temperature and rainfalls) are calculated. Using the time-series trend analysis method, average values of the selected climate variables are researched for their behavioural change. Econometrics techniques are used on the time series data with the help of STATA software for various analyses and purposes.

3. RESULTS AND DISCUSSION

3.1 TREND ANALYSIS

3.1.1 Climate Change in the North East India

The paper has considered three representative elements of climate change in the North-East India: Average Minimum Temperature, Average Maximum Temperature and Average Rainfall. Though there is a clear increasing trend in the case of average minimum and maximum temperature, the change in average rainfalls is not significant in this region. The trend lines of the mean-maximum temperature, mean-minimum temperature and the average rainfalls in a year are shown in figures 1, 2 and 3 respectively.

Figure 1 Average Maximum Temperature (Year wise)

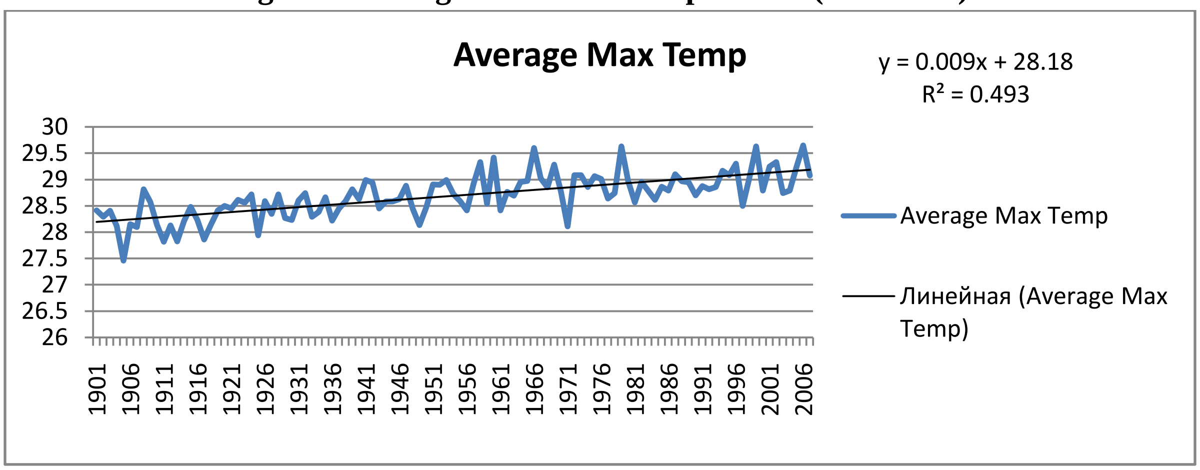


Figure 2 Average Minimum Temperature (Year wise)

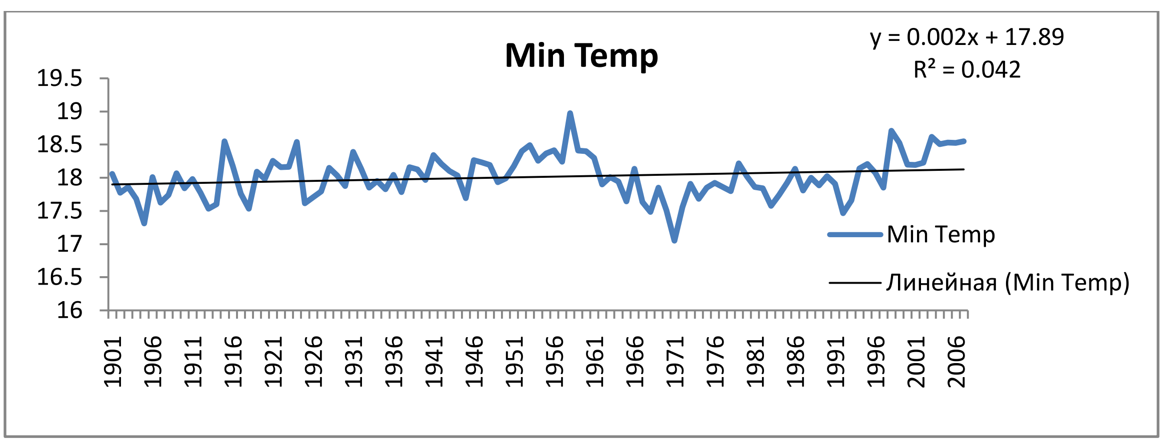
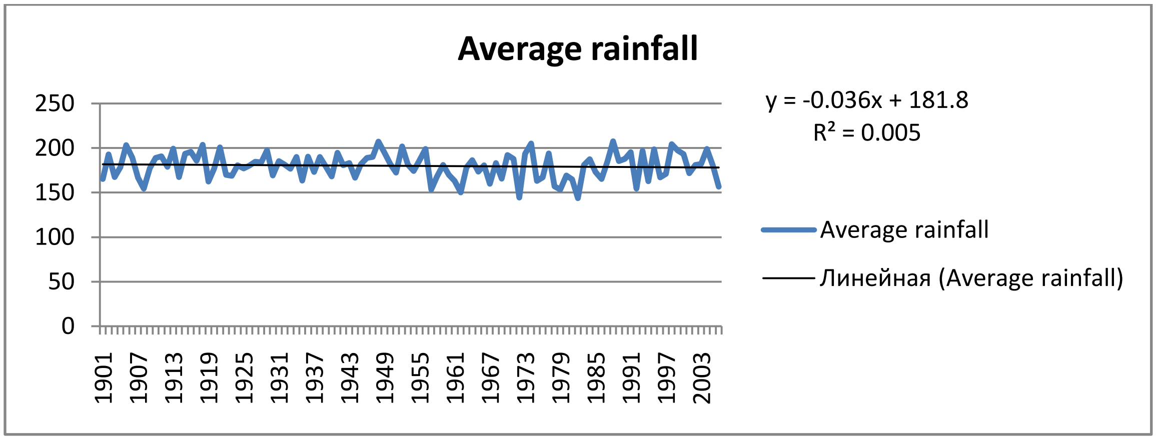


Figure 3 Average Rainfall (Year wise)



3.1.2 Relationship of Climate Change with Urbanisation

Urbanisation in India is denoted in terms of the percentage of the urban population in total population. In the case of North-Eastern states of India the general trend of urbanisation is as shown in figure 4below. The percentage of urban population to the total population rises continuously in four decades. The logarithmic trend of urbanisation as shown in figure 5demonstrates that the rate of urbanisation increases with a high rate from the year 1971 to 1991, and slows down form year 1991 to 2001 but, again it shows an increase from 2001 onwards.

Figure 4 Urbanisation in the North- East India

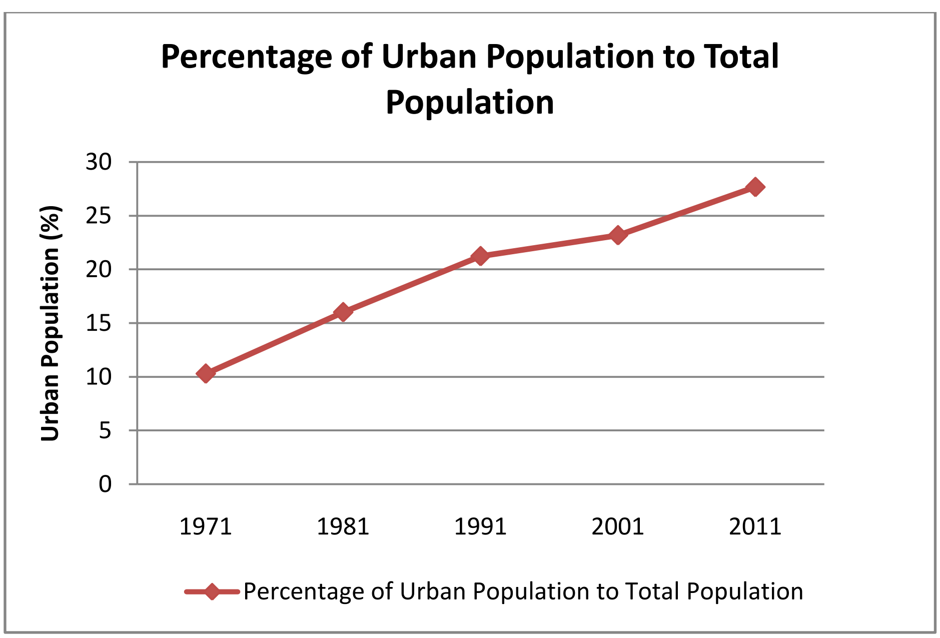
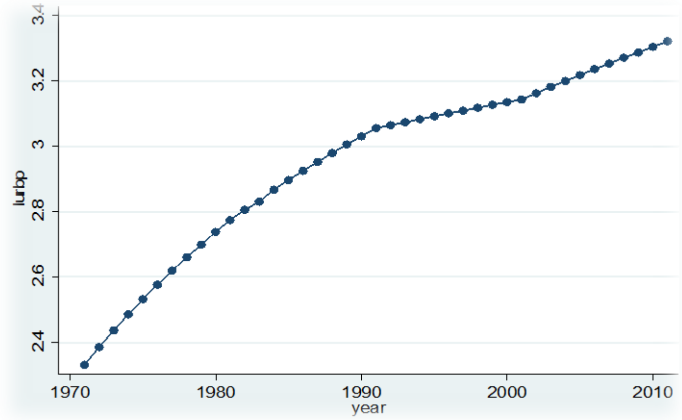


Figure 5 Trend of Urbanisation on Logarithmic Scale



The percentage of urban population in the total population has increased from 10.3 in 1971 to 16 in the year 1981. It further increased up to 21 percent in the year 1991. The rapid urbanisation since 1970s shows some effective similarities with the change of climate in this region. The after effect of rapid urbanisation is observed in all the three elements of climate change considered in the paper. The average decadal maximum temperature shows a significant rise from 1981 onwards, that is, the decade after the rapid urbanisation started in the region (Figure 6). Similar trend is observed in the case of average decadal minimum temperature of the region which is shown in figure 7 below.

Figure 6 Average Decadal maximum temperatures in North-East India

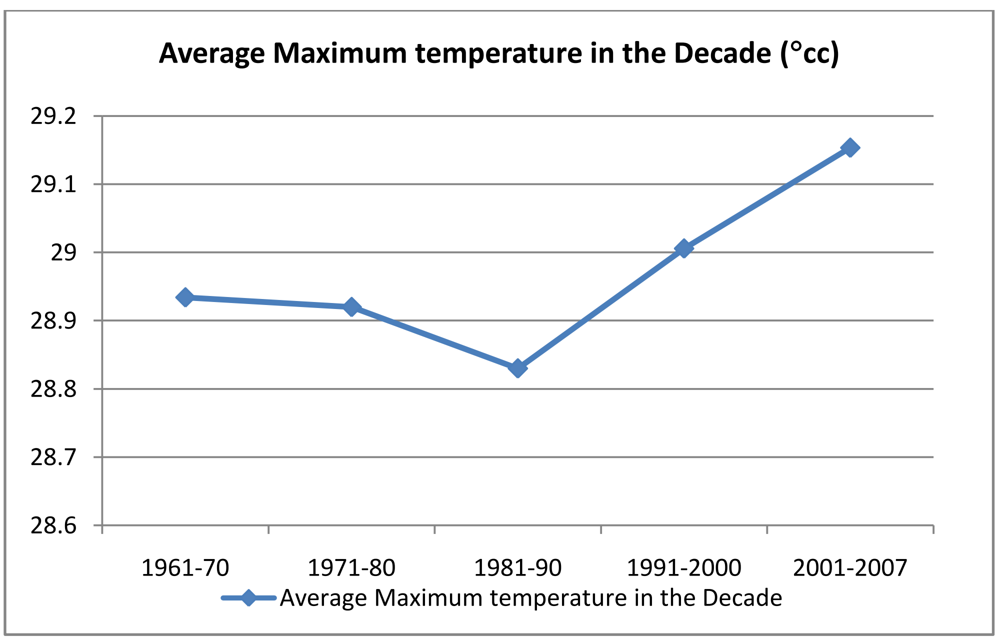
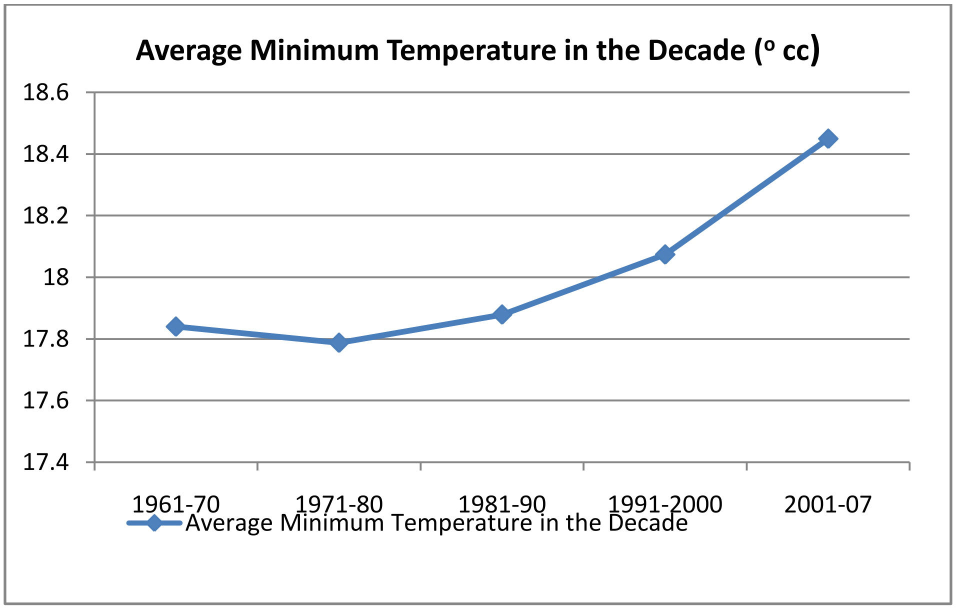


Figure 7Average Decadal minimum temperatures in North-East India



Though there has not been any significant change in the average rainfall in this region, some month wise changes in the rainfall received can be observed and are conspicuous. The decadal average of the rainfall in the month of June shows a considerable decline from 1970s. Figure 8 shows the change in the average rainfalls in the month of June in this region. On the other hand, the average rainfalls in the month of December have increased sharply from the decade of 1970s which can be easily observed from figure 9 shown below. All these changes in rainfalls are not observed in the previous decades when the urban population was only about ten percent of the total population.

Figure 8 Average Decadal Rainfalls in June (in mm)

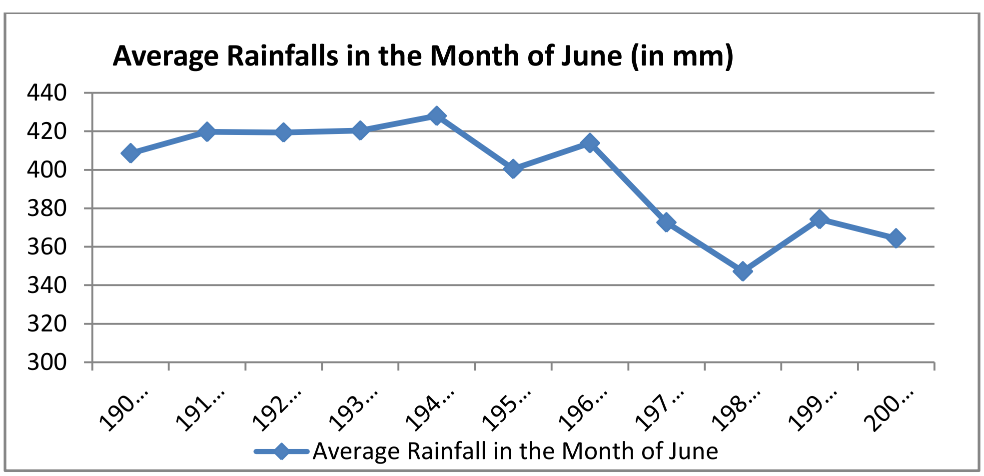
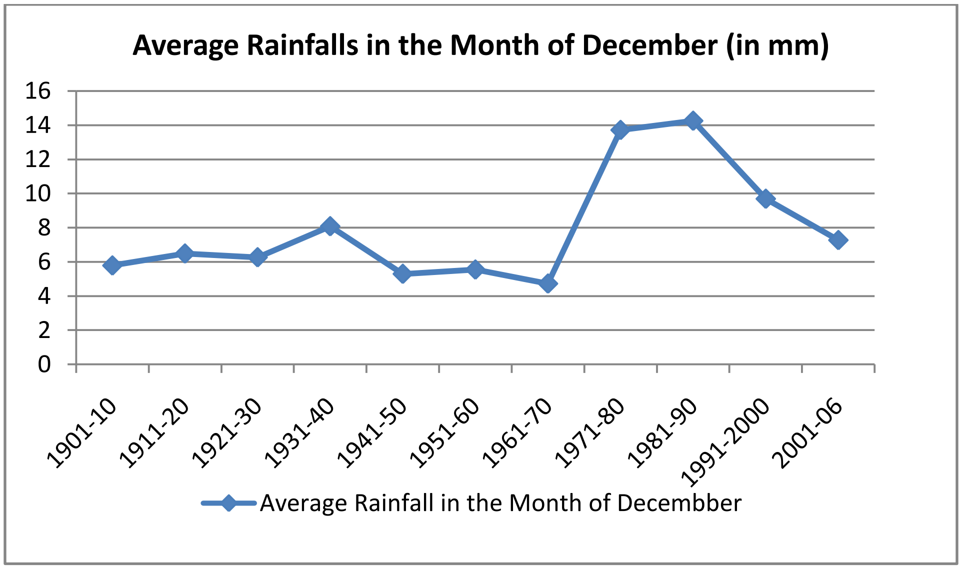


Figure 9 Average Decadal Rainfalls in December (in mm)



All these figures indicate some relationships between the urbanisation and climate change in the North-East India which needs to be further verified by statistical and econometrical tools. After which one may be able to make some propositions or conclusions.

4. URBANISATION AND CLIMATE CHANGE: AN ECONOMETRIC ANALYSIS

4.1 Unit root test

Since the paper has considered three variables for climate change (Maximum Temperature, Minimum Temperature and Rainfalls) and the variable ‘percentage of urban population to the total population’ for urbanisation, there are four time series data available for calculations. Assuming that the characteristics of the time series data do not change, all the series have been converted on logarithmic scale to avoid the problems of the heteros-causticity and violent fluctuations in the data. Moreover, the paper concerns about the change in the climate of the region, therefore logarithmic processing has an additional advantage that it suits many further analyses. But stationary test of the variables of the time series data is the precondition for any econometric testing or operations (Zhao and Wang, 2015; Yang, Yuan and Sun, 2012). Therefore, all the series have been tested for their stationary characteristics against the null hypothesis that the series are non -stationary, and the results have been reported in table 1.ADF (Augmented Dickey Fuller) unit roots test is used in this paper to test the stability of the time series data of the variables. The test is carried out with individual trends and intercepts for each variable, and the optimal lag lengths are selected using the *lag order determination criteria* available in STATA11(Stata is a general-purpose statistical software package created in 1985 by StataCorp. Most of its users work in research, especially in the fields of economics, sociology, political science, biomedicine and epidemiology).

H_0 = there is unit root in the series

Table 1 Results of ADF unit root test

Variables	**ADF test data**	**Test type (*ctp*)**	**5% critical value**	**Conclusion**
Log of mintemp	-1.139	ct1	-3.544	Non-stationary
dlogmintemp	-6.546	c00	-2.961	Stationary
Log of maxtemp	-0.813	ct1	-3.544	Non-stationary
dlogmaxtemp	-6.592	c00	-2.961	Stationary
Log of rain	-1.472	ct3	-3.552	Non-stationary
dlograin	-5.510	c02	-2.966	Stationary
lturbp	-3.156	ct2	-3.552	Non-stationary
dlturbp	-4.523	c01	-2.966	Stationary

Notes: ***c*** means intercept, ***t*** means trend term, and ***p*** means lag orders. Lag order is determined by lag-order selection criteria; ***d*** means 1st order difference.

The dlogmintemp, dlogmaxtemp and dlograin refer to the series of the variables average minimum temperature, average maximum temperature and average rainfalls at first order differences respectively. According to the studies of the Liddle (2013) and Zhao and Wang (2015), urbanization, which is constrained to be between 0 and 1, cannot technically be integrated of order *I* (1). Thus, the variables of urbanization (the share of urban population) have been transformed into truncated form (*TURBP)* according to Equation (*) given below. The specific formula for the transformation is as follows:

$$TURBP = \left(\frac{xi - Min\ URBP}{Max\ URBP - MinURBP}\right)\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(*)$$

Where x_i is the value of individual variable and Min URBP and Max URBP are the minimum and maximum values among all the values of the variable urbanisation. Thus, lturbp and dlturbp in table 1 indicates the log value of truncated urbanisation at zero and first order respectively.

The series of all the four variables are not stationary at their log scale as the null hypothesis could not be rejected. But all the variables are found to be stationary at the first order difference level having single integration or *I* (1). The null hypothesis cannot be accepted at the first difference level of the variables.

4.2 Causal relationship

To estimate the causal relationship between the urbanisation and the three elements of climate change a simple OLS regression has been performed on the log values of each of the variables. The indicators of climate change are the dependent variables and urbanisation serves as the independent variables in this regression analysis. In all the three cases the urbanisation shows a significant effect as depicted in Table 2.

Table 2 OLS Results on Logarithmic Scale

	Dependent Variables		
	Model1	Model2	Model3
Independent Variable	Log Mintemp	Log Maxtemp	Log Rainfalls
Log TURBP	0.035***	0.059**	0.084***
	(0.011)	(0.028)	(0.029)
Constant	2.939***	3.460***	5.289***
	(0.013)	(0.031)	(0.032)
Observations	40	40	40
R-squared	0.201	0.105	0.183

*** p<0.01, ** p<0.05, * p<0.1. Standard errors in parentheses

But any regression analysis without the stationary series of all the included variables may consist many flaws. Additionally, the indicators of climate change may be related to their past values. Therefore, to avoid such problems an OLS regression has been performed on the stationary series of all the variables, that is, at first difference level with integrated degree of order I(1). Two different regression equations for each of the dependent variables using their past values have been run for robustness of the analysis. The equations of regression analysis are as follows:

$$\text{Log } Y_i\ (t) = \alpha_i + \beta_1 \log \text{TURBP}\ (t) + \beta_2 \log Y_i\ (t-1) + \varepsilon \qquad (1)$$

$$\text{Log}Y_i\ (t) = \alpha_i + \beta_1 \log \text{TURBP}\ (t) + \beta_2 \log Y_i\ (t-1) + \beta_3 \log Y_i\ (t-2) + \varepsilon \qquad (2)$$

Yi (t) are the three climate change related dependent variables: Mean-Minimum temperature, Mean-Maximum temperature and Average Rainfalls in a year. Log TURBP indicates the log values of the truncated urbanisation (normalised value of the urbanisation). t, t-1 and t-2 are the time periods (present, one year before and two years before) respectively. In all the cases the percentage change in the urbanisation (Log of truncated Urbanisation) shows a significant effect on all the three indicators of climate change used in the analysis. The results of regression analysis are given in appendix A. The percentage change in the Urbanisation shows its causal effect on the percentage change in all these three indicators of climate change at various significance level: (a) Average Rainfalls (at 1% significance level) (b) Average minimum temperature (at 1% significance level) and (c) Average maximum temperature (at 10% significance level). It means the effect of rise in urbanisation is more evident in the case of changes in average rainfalls and average minimum temperature in this region than the changes in average maximum temperature.

4.3 Co-integration Test

To verify the long run relationship between the urbanisation and the various indicators of climate change a co-integration analysis is done. Since all the variables are stationary at the first difference level I (1), one can proceed to perform the co-integration test. It is a two step procedure: in the first step residual term (e_t) has been calculated for each pair of variables using dual regression analysis (DOLS) and then in the second step an Augmented Dickey Fuller Test (ADF) is conducted to examine the relationship, i.e. stationary nature of the residual terms. In the dual regression analysis the urbanisation shows a significant effect on all the three related variables of the climate change while any such causal effect has not been found from these indicators on the urbanisation. The results are quite reasonable as urbanisation may cause climate change but there is no sense in any such statement regarding climate change causes urbanisation. The results of the regression analysis are reported in Table 3 and the results of Augmented Dickey Fuller Tests are reported in Table 4, 5 and 6. The long run relationship between the three different indicators of climate change (average minimum temperature in a year, average maximum temperature in a year and the average rainfalls in a year) and the urbanisation is satisfied through this test. On the basis of the results obtained after the co-integration analysis one may conclude that the urbanisation has a long term impact on the climate of this region.

The various econometric tests conducted to verify the causal effect of the rise in urban population (Urbanisation) on the climate change through three different indicators, indicate towards the confirmation of this cause and effect relationship.

Table 3 Results of Regression Analysis (Co-integration)

	Model 1		Model 2		Model 3	
	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLE	Log mintemp	var(e.Logmintemp)	Log maxtemp	var(e.Log maxtemp)	Log rain	var(e.Log rain)
Log turbp	0.035***		0.059**		0.084***	
	(0.011)		(0.027)		(0.028)	
Constant	2.939***	0.003***	3.460***	0.018***	5.289***	0.019***
	(0.012)	(0.001)	(0.030)	(0.004)	(0.031)	(0.004)
Observations	40	40	40	40	40	40

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 4 ADF Test in case of Minimum Temperature and Urbanisation

```
. dfuller uhat1, lags(0)

Dickey-Fuller test for unit root                   Number of obs   =        38
```

	Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value
		Interpolated Dickey-Fuller		
Z(t)	-6.593	-3.662	-2.964	-2.614

MacKinnon approximate p-value for Z(t) = 0.0000

Table 5 ADF Test in case of Maximum Temperature and Urbanisation

```
. dfuller uhat2, lags(0)

Dickey-Fuller test for unit root                   Number of obs   =        38
```

	Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value
		Interpolated Dickey-Fuller		
Z(t)	-6.499	-3.662	-2.964	-2.614

MacKinnon approximate p-value for Z(t) = 0.0000

Table 6 ADF Test in case of Average Rainfalls and Urbanisation

```
. dfuller uhat3, lags(2)

Augmented Dickey-Fuller test for unit root         Number of obs   =        36
```

	Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value
		Interpolated Dickey-Fuller		
Z(t)	-5.234	-3.675	-2.969	-2.617

MacKinnon approximate p-value for Z(t) = 0.0000

5. CONCLUSION

Urbanisation has an impact on the climate. The various econometric tests provide empirical evidences in case of north-east India. All the tests confirm that the rise in the share of urban population in the total population of the north-eastern region of India causes significant changes in the climate of this region in terms of: mean-minimum temperature, mean- maximum temperature and average rainfalls in a year. The changes in climate factors are also visible clearly in the decades on and after urbanisation have increased in the region.Months of winter (December, January and February) are becoming warmer with rising average minimum temperatures over the decades. There has been a considerable decline in the rainfall in the month of June. On the other hand average rainfall has increased significantly in the month of December, which is harmful for the agriculture. The rising temperature and unseasonal rainfall even with little industrialization is a matter of concern for this region. Though the size of the urban population is less than 30 percent in most of the states of the North-East India except Manipur and Mizoram, further urbanization and any industrial development may lead to serious environmental concerns in the region.

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APPENDIX A

Regression of mean-minimum temperature on urbanisation at t and mean-minimum att-1 time period

```
. regress  lavgmintemp lturbp  dlavgmintemp

      Source |       SS       df       MS              Number of obs =      40
-------------+------------------------------           F(  2,    37) =   11.08
       Model |  .055113101     2  .027556551           Prob > F      =  0.0002
    Residual |  .092013114    37  .002486841           R-squared     =  0.3746
-------------+------------------------------           Adj R-squared =  0.3408
       Total |  .147126215    39  .003772467           Root MSE      =  .04987

------------------------------------------------------------------------------
 lavgmintemp |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      lturbp |   .0343419   .0101988     3.37   0.002     .0136772    .0550067
dlavgmintemp |   .8635771   .2693223     3.21   0.003     .3178784    1.409276
       _cons |   2.933403   .0113678   258.04   0.000     2.910369    2.956436
```

Regression of mean-minimum temperature on urbanisation at t and mean-minimum at t-1 and t-2 time period

```
. regress  lavgmintemp lturbp dlavgmintemp ddlavgmintemp

      Source |       SS       df       MS              Number of obs =      39
-------------+------------------------------           F(  3,    35) =   14.24
       Model |  .079663437     3  .026554479           Prob > F      =  0.0000
    Residual |   .06524998    35  .001864285           R-squared     =  0.5497
-------------+------------------------------           Adj R-squared =  0.5111
       Total |  .144913417    38  .003813511           Root MSE      =  .04318

------------------------------------------------------------------------------
 lavgmintemp |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      lturbp |   .0360937   .0106302     3.40   0.002     .0145133    .0576741
dlavgmintemp |   1.772693   .3451262     5.14   0.000     1.072049    2.473336
ddlavgmint~p |  -.8723578   .2341634    -3.73   0.001    -1.347735   -.3969808
       _cons |   2.928211   .0106527   274.88   0.000     2.906585    2.949838
------------------------------------------------------------------------------
```

Regression of mean-maximum temperature on urbanisation at t and mean-max temperature at t-1 time period

```
. regress  lavgmaxtemp lturbp dlavgmaxtemp

      Source |       SS       df       MS              Number of obs =      40
-------------+------------------------------           F(  2,    37) =    8.01
       Model |  .238793944     2  .119396972           Prob > F      =  0.0013
    Residual |  .551702797    37  .014910886           R-squared     =  0.3021
-------------+------------------------------           Adj R-squared =  0.2644
       Total |  .790496741    39  .020269147           Root MSE      =  .12211

------------------------------------------------------------------------------
 lavgmaxtemp |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      lturbp |   .0501395   .0251132     2.00   0.053    -.0007446    .1010236
dlavgmaxtemp |   .8522048    .263679     3.23   0.003     .3179404    1.386469
       _cons |    3.44212   .0279788   123.03   0.000      3.38543    3.498811
------------------------------------------------------------------------------
```

Regression of mean-maximum temperature on urbanisation at t and mean-maximum at t-1 and t-2 time period

```
. regress  lavgmaxtemp lturbp dlavgmaxtemp ddlavgmaxtemp

      Source |       SS       df       MS              Number of obs =      39
-------------+------------------------------           F(  3,    35) =   12.34
       Model |    .4052797     3  .135093233           Prob > F      =  0.0000
    Residual |   .38328616    35  .010951033           R-squared     =  0.5139
-------------+------------------------------           Adj R-squared =  0.4723
       Total |  .788565861    38  .020751733           Root MSE      =  .10465

------------------------------------------------------------------------------
 lavgmaxtemp |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      lturbp |   .0474602   .0261655     1.81   0.078    -.0056585     .100579
dlavgmaxtemp |   1.791916   .3392166     5.28   0.000      1.10327    2.480563
ddlavgmaxt~p |  -.8736054   .2278394    -3.83   0.001    -1.336144   -.4110668
       _cons |   3.426445   .0260877   131.34   0.000     3.373484    3.479406
------------------------------------------------------------------------------
```

Regression of average annual rainfalls on urbanisation at t and average annual rainfalls at t-1 time period

```
. regress lavgrain lturbp dlavgrain
```

Source	SS	df	MS
Model	.415077934	2	.207538967
Residual	.501672282	37	.01355871
Total	.916750216	39	.023506416

Number of obs =	40
F(2, 37) =	15.31
Prob > F =	0.0000
R-squared =	0.4528
Adj R-squared =	0.4232
Root MSE =	.11644

lavgrain	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
lturbp	.0726824	.0239454	3.04	0.004	.0241644	.1212004
dlavgrain	.5142097	.1203285	4.27	0.000	.2704011	.7580184
_cons	5.27625	.0263389	200.32	0.000	5.222882	5.329617

Regression of average annual rainfalls on urbanisation at t and average annual rainfalls at t-1 and t-2 time period

```
. regress lavgrain lturbp dlavgrain ddlavgrain
```

Source	SS	df	MS
Model	.488482577	3	.162827526
Residual	.364168205	35	.010404806
Total	.852650782	38	.022438178

Number of obs =	39
F(3, 35) =	15.65
Prob > F =	0.0000
R-squared =	0.5729
Adj R-squared =	0.5363
Root MSE =	.102

lavgrain	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
lturbp	.0782939	.0250512	3.13	0.004	.0274373	.1291504
dlavgrain	1.130931	.2005232	5.64	0.000	.7238475	1.538015
ddlavgrain	-.4074568	.1165094	-3.50	0.001	-.6439834	-.1709302
_cons	5.271996	.0243693	216.34	0.000	5.222524	5.321469

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