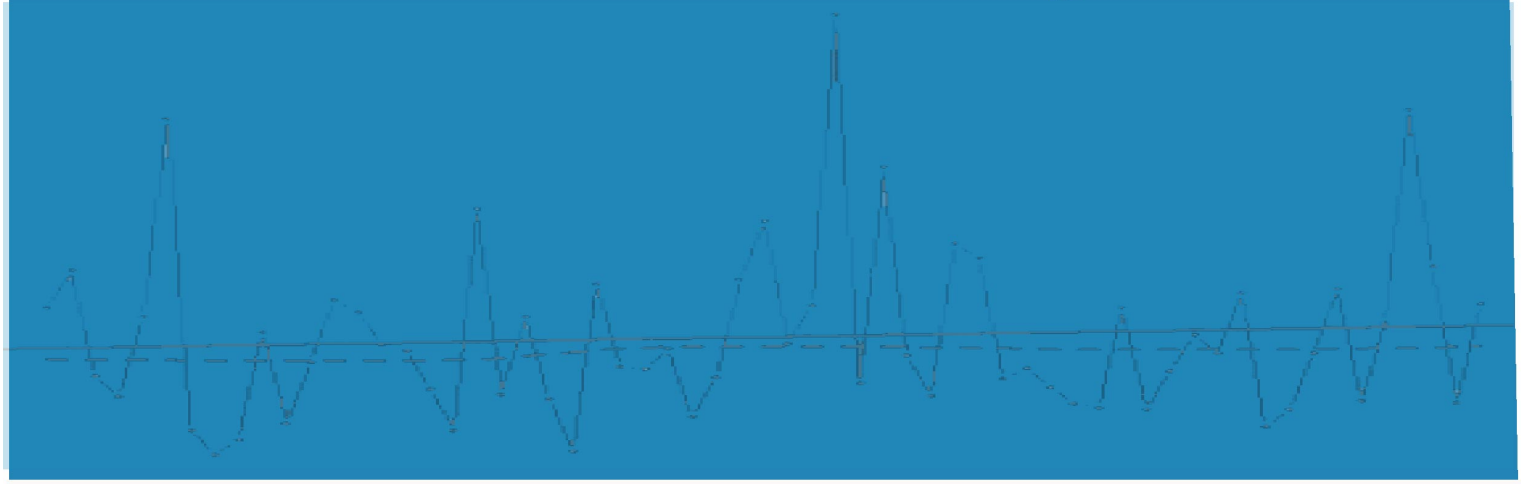
Developing Dynamic Web-GIS based Early Warning System for the Communities at Landslide Risks in Chittagong Metropolitan Area, Bangladesh

Report On

Rainfall Pattern Modeling



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Rainfall Pattern Modeling Report

Submitted to

International Centre for Integrated Mountain Development (ICIMOD)

Submitted by

BUET-Japan Institute of Disaster Prevention and Urban Safety (BUET-JIDPUS); Bangladesh University of Engineering and Technology (BUET), Dhaka-1000, Bangladesh

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January 2015

1. Background

The objective of rainfall modeling is to predict the future rainfall pattern of Chittagong Metropolitan Area. To perform this modeling, rainfall data (1950-2010) on daily basis is collected from the 'Bangladesh Meteorological Department (BMD)'. BMD collects daily basis precipitation data (unit: Millimetre) from 34 stations for all over Bangladesh. But there are only two stations that collect the precipitation data for Chittagong City. Moreover, approximately 2% data were found missing. The missing data were then adjusted based on the rainfall trend of the previous years.

2. Methodology

At first, the rainfall pattern based on the previous years is analysed using "RClimDex". The RClimDex is developed and maintained by Xuebin Zhang and Feng Yang at the Climate Research Branch of Meteorological Service of Canada. ClimDex is a Microsoft Excel based program that provides an easy-to-use software package for the calculation of indices of climate extremes for monitoring and detecting climate change. It runs on "R", which is free, robust and powerful software for statistical analysis and graphics [1]. In the later section, based on the past trend, the future rainfall pattern is predicted using 'IDRISI Selva' and 'ArcGIS 10.2' software.

2.1. Indices Used

The following indices are used to analyse the precipitation pattern [1]:

ID	Indicator Name	Definitions	UNITS
RX1day	Max 1-day precipitation amount	Monthly maximum 1-day precipitation	mm
Rx5day	Max 5-day precipitation amount	Monthly maximum consecutive 5-day precipitation	mm
SDII	Simple daily intensity index	Annual total precipitation divided by the number of wet days (defined as PRCP>=1.0mm) in the year	Mm/day
R10	Number of heavy precipitation days	Annual count of days when PRCP>=10mm	Days
R20	Number of very heavy precipitation days	Annual count of days when PRCP>=20mm	Days
Rnn	Number of days above nn mm	Annual count of days when PRCP>=nn mm, nn is user defined threshold	Days
CDD	Consecutive dry days	Maximum number of consecutive days with RR<1mm	Days

CWD	Consecutive wet days	Maximum number of consecutive days with RR>=1mm	Days
R95p	Very wet days	Annual total PRCP when RR>95th percentile	mm
R99p	Extremely wet days	Annual total PRCP when RR>99th percentile	mm
PRCPTOT	Annual total wet-day precipitation	Annual total PRCP in wet days (RR>=1mm)	mm

The definitions of the climatic indices are as follows [1]:

1. RX1day

Let RR_{ij} be the daily precipitation amount on day i in period j. Then maximum 1-day values for period j are:

$Rx1day_j = \max(RR_{ij})$

2. Rx5day

Let RR_{kj} be the precipitation amount for the 5-day interval ending k, period j. Then maximum 5-day values for period j are:

$Rx5day_j = \max(RR_{kj})$

3. SDII

Let RR_{wj} be the daily precipitation amount on wet days, $w(RR \geq 1mm)$ in period j. If W represents number of wet days in j, then:

$$SDII_j = \frac{\sum_{w=1}^{W} RR_{wj}}{W}$$

4. R10

Let RR_{ij} be the daily precipitation amount on day i in period j. Count the number of days where:

$RR_{ij} \geq 10mm$

5. R20

Let RR_{ij} be the daily precipitation amount on day i in period j. Count the number of days where:

$RR_{ij} \geq 20mm$

6. Rnn

Let RR_{ij} be the daily precipitation amount on day i in period j. If nn represents any reasonable daily precipitation value then, count the number of days where:

$RR_{ij} \geq nnmm$

7. CDD

Let RR_{ij} be the daily precipitation amount on day i in period j. Count the largest number of consecutive days where:

$RR_{ij} < 1mm$

8. CWD

Let RR_{ij} be the daily precipitation amount on day i in period j. Count the largest number of consecutive days where:

$RR_{ij} \geq 1mm$

9. R95pTOT

Let RR_{wj} be the daily precipitation amount on a wet day $w(RR \geq 1.0mm)$ in period j and let $RR_{wn}95$ be the 95th percentile of precipitation on wet days in the 1950-2010 period. If W represents the number of wet days in the period, then:

$$R95p_j = \sum_{w=1}^{W} RR_{wj} \text{ where } RR_{wj} > RR_{wn}95$$

10. R99p

Let RR_{wj} be the daily precipitation amount on a wet day $w(RR \geq 1.0mm)$ in period j and let $RR_{wn}99$ be the 99th percentile of precipitation on wet days in the 1950-2010 period. If W represents number of wet days in the period, then:

$$R99p_j = \sum_{w=1}^{W} RR_{wj} \text{ where } RR_{wj} > RR_{wn}99$$

11. PRCPTOT

Let RR_{ij} be the daily precipitation amount on day i in period j. If I represents the number of days in j, then

$$PRCPTOT_j = \sum_{i=1}^{I} RR_{ij}$$

2.2. Identifying the Rainfall Pattern in Bangladesh

The daily rainfall data from 1950-2010 is collected from the Bangladesh Meteorological Department (BMD). There are in total 34 rainfall measuring stations in Bangladesh, as defined by BMD (Figure 1). All the maps are projected in 'Bangladesh Transverse Mercator (BTM)' projection system and the datum is used as

'Everest 1830'. The month and yearly precipitation (mm) graphs are attached in Appendix-I.

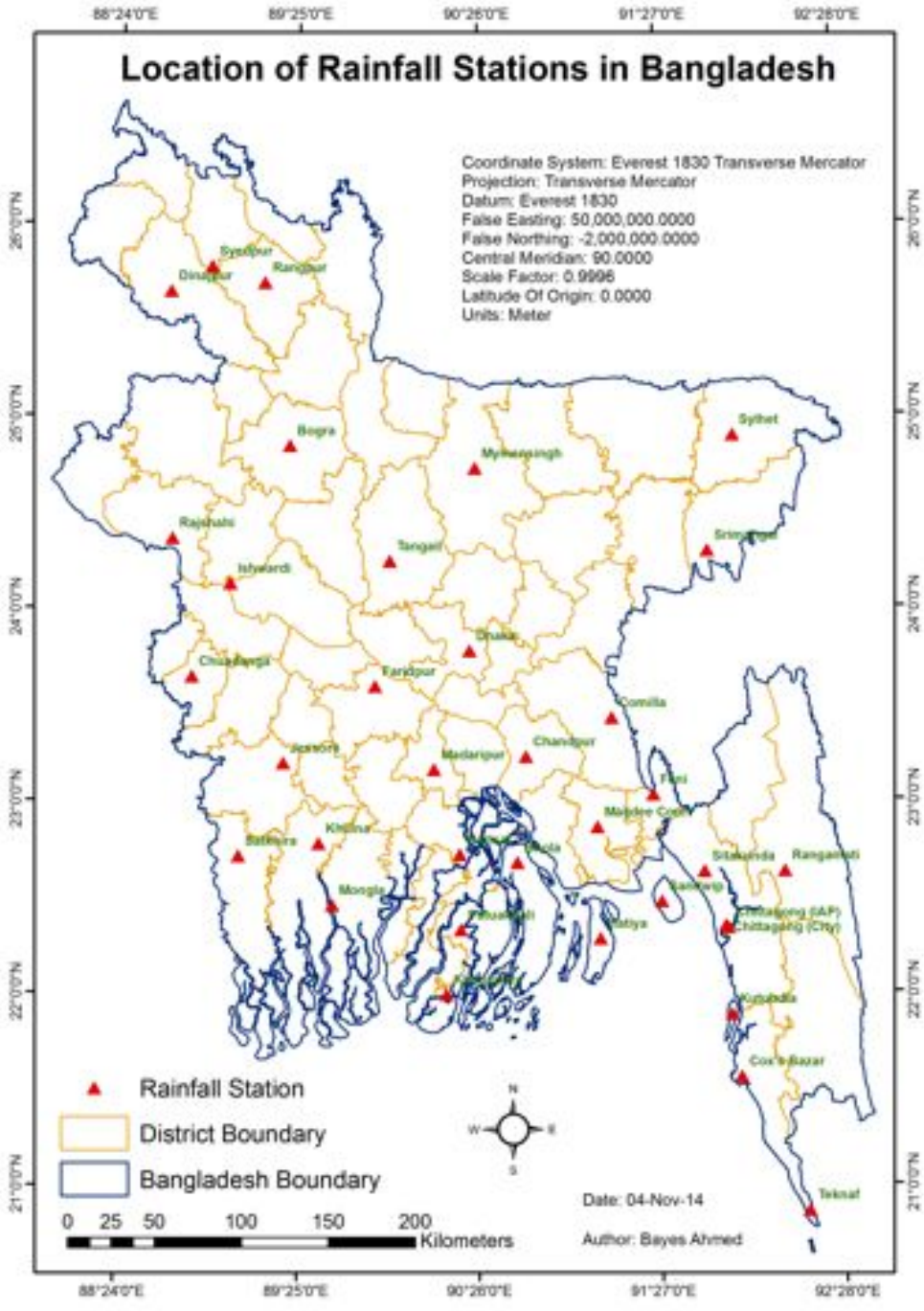


Figure 1. Location of the Rainfall Gauges in Bangladesh

Later, based on the collected database, 'Krigging' interpolation method was implemented in 'ArcGIS 10.2' to generate the rainfall pattern map of Bangladesh. It is found that 'Chittagong District' is located within the 'very high' to 'moderately high' rainfall zone in Bangladesh (Figure 2).

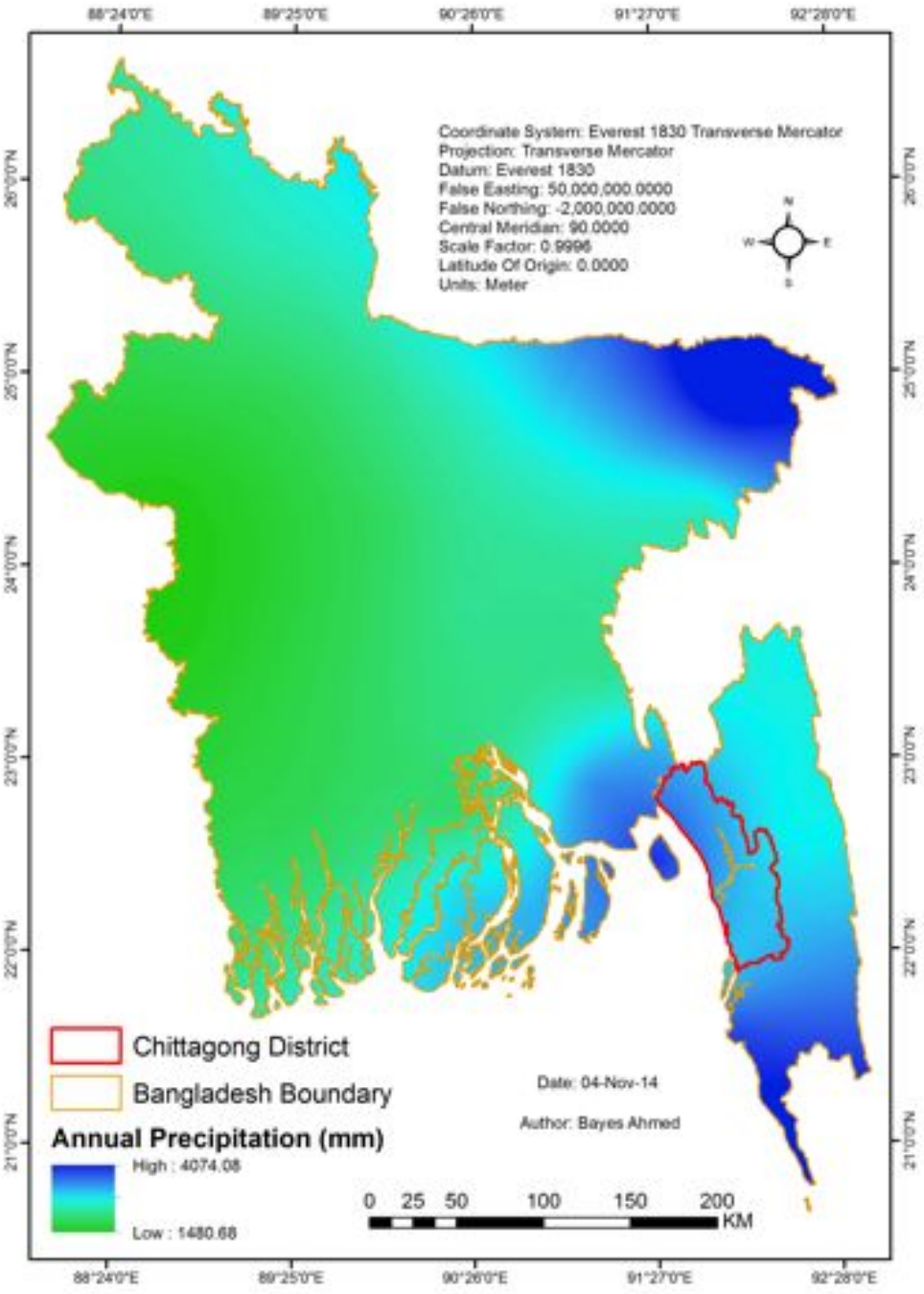


Figure 2. Annual Rainfall Pattern Map of Bangladesh

The scenario is found same for the Monsoon season. The north-east and south-east parts of Bangladesh face maximum rainfall during the monsoon (Figure 3). Here, the Monsoon season comprises of the months from April-October. It is also found that June and July are months when the intensity of rainfall is the highest (Appendix-II). The rainfall pattern maps of Bangladesh during the rainy season are attached in Appendix-II.

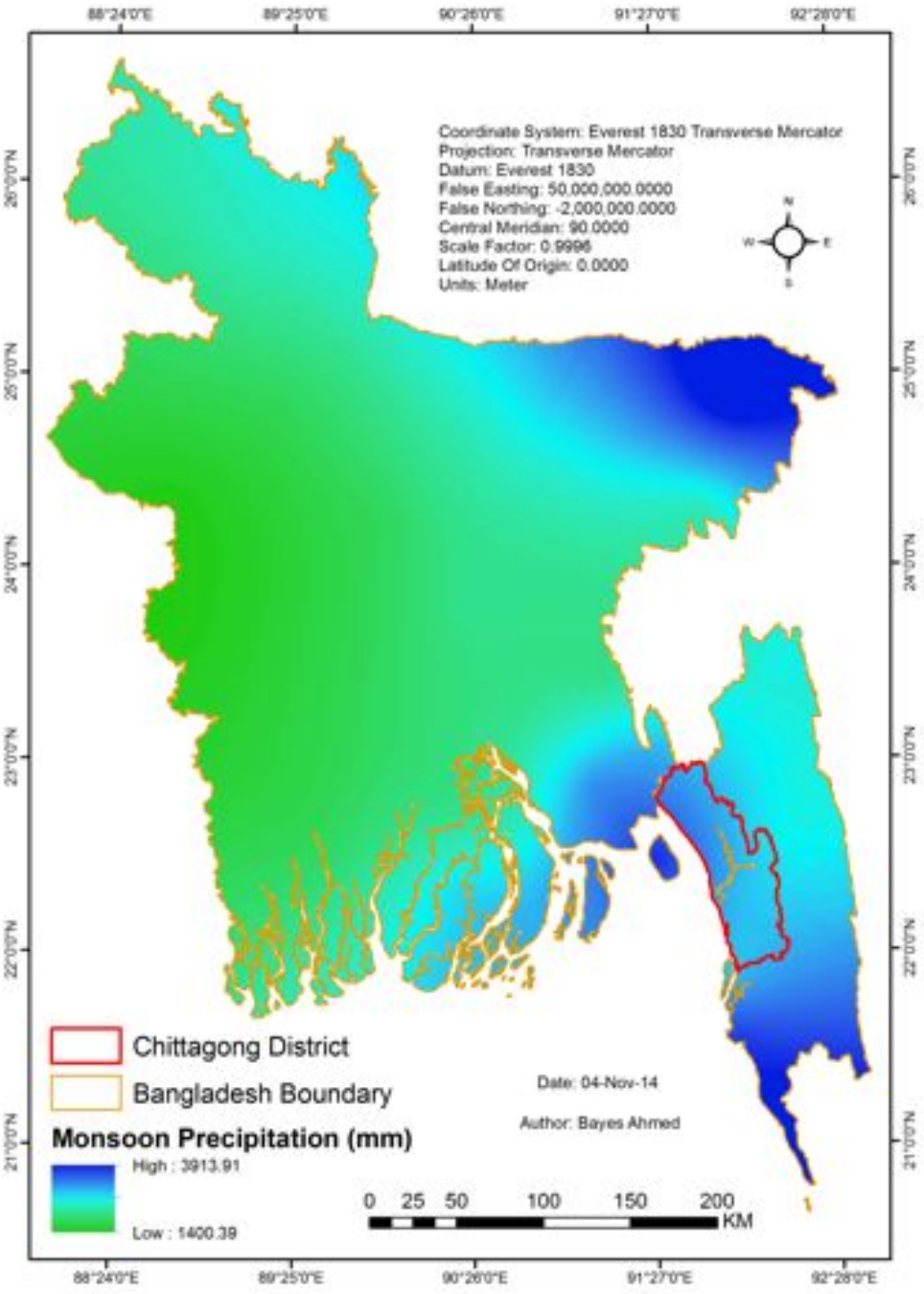


Figure 3. Monsoon Rainfall Pattern Map of Bangladesh

2.3. Trend Analysis

'RClimdex (version 1.0)' is used to analyse the trends of the precipitation indices for Chittagong. All the generated plots and the indices are attached in Appendix-III-VI. Moreover, the result of the numerical trend analysis is depicted in Table 1. 'Rnn' is calculated using 50mm, 75mm and 100mm of rainfall values (Appendix-III, Appendix-IV and Table 1). But here the rainfall threshold limit is taken as 50mm [2].

Table 1. Trends of the Rainfall Indices (1950-2010)

Indices	Starting Year	End Year	Slope	Slope Error	P_Value
Rx1day	1950	2010	0.335	0.564	0.554
Rx5day	1950	2010	-0.030	1.189	0.980
SDII	1950	2010	0.001	0.032	0.969
R10mm	**1950**	**2010**	**0.053**	**0.062**	**0.394**
R20mm	**1950**	**2010**	**0.054**	**0.051**	**0.296**
R50mm	1950	2010	-0.005	0.033	0.883
CDD	1950	2010	0.045	0.187	0.809
CWD	1950	2010	-0.025	0.034	0.465
R95p	1950	2010	-2.552	3.486	0.467
R99p	1950	2010	-1.770	2.543	0.489
PrcpTot	1950	2010	0.763	4.071	0.852

2.4. Generating Climate Scenarios

Climate change is defined as a difference over a period of time (with respect to a baseline or a reference period) and corresponds to a statistical significant trend of mean climate or its variability, persistent over a long period of time (e.g. decades or more). Climate change may be due to both natural (i.e. internal or external processes of the climate system) as well as anthropogenic forcing (ex. increase in concentrations of greenhouse gases) [3]. A climate change scenario is not a prediction of future climate. It is a plausible future climate that has been constructed for explicit use in investigating the potential consequences of anthropogenic climate change [3,4]. Here: CLIMATE SCENARIO = CURRENT CLIMATE + CLIMATE CHANGE SCENARIO [5].

In this section, the climate scenarios focusing on the rainfall pattern are generated from the Canadian Climate Data and Scenarios (CCDS). The CCDS is an interface for distributing climate data and climate change scenarios. Climate change scenarios are provided from numerous international research centres, in support of the Intergovernmental Panel for Climate Change (IPCC) assessments. Results from the fourth (AR4) assessments are used in this report [3]. For selecting the scenarios, the guidelines from the CCDS are followed [3]. The 'simple daily intensity index (mm/day)', 'total (mm/day)', 'days > 10 mm/d (day)', and '5 day maximum (mm) precipitation' variables are selected for analysing the rainfall trend in Chittagong Metropolitan Area (CMA). For each index, two different scenarios are generated

(Figure 4-7). The projections (till 2030) of the precipitation trends are performed based on the past database (from 1960).

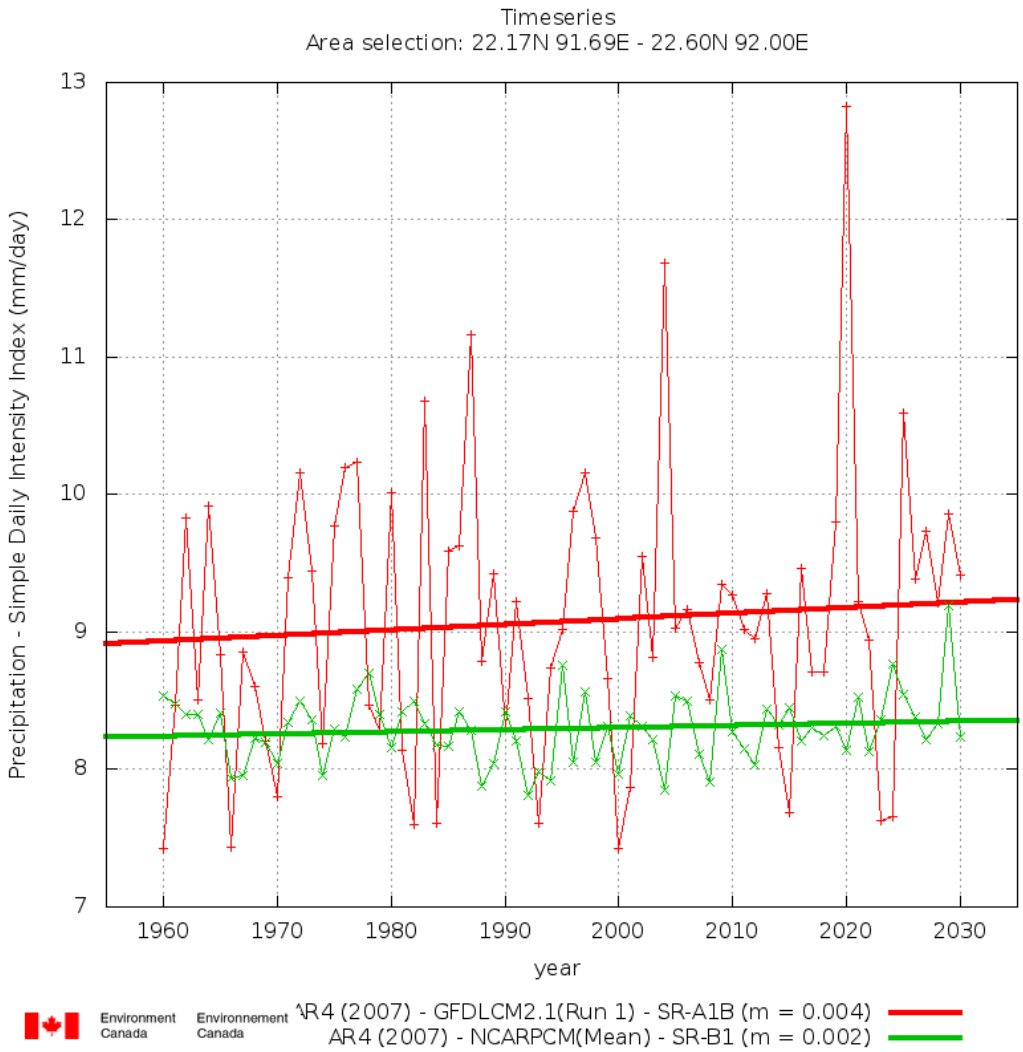


Figure 4. Trend-line Showing the Daily Precipitation Intensity Index (mm/day) of CMA from 1960-2030

3. Results and Discussions

The following results are achieved from the rainfall analysis (1950-2010):

i. The north-east and south-east hilly districts of Bangladesh counter heavy rainfall during the monsoon (Figure 2).

ii. **Chittagong City is located in high rainfall zone** (Figure 2).

iii. The trend of monthly maximum 1-day precipitation is increasing (Approx. 33%). It means the wet months are increasing in CMA.

iv. The number of monthly maximum consecutive 5-day precipitation is decreasing (Approx. 3%).

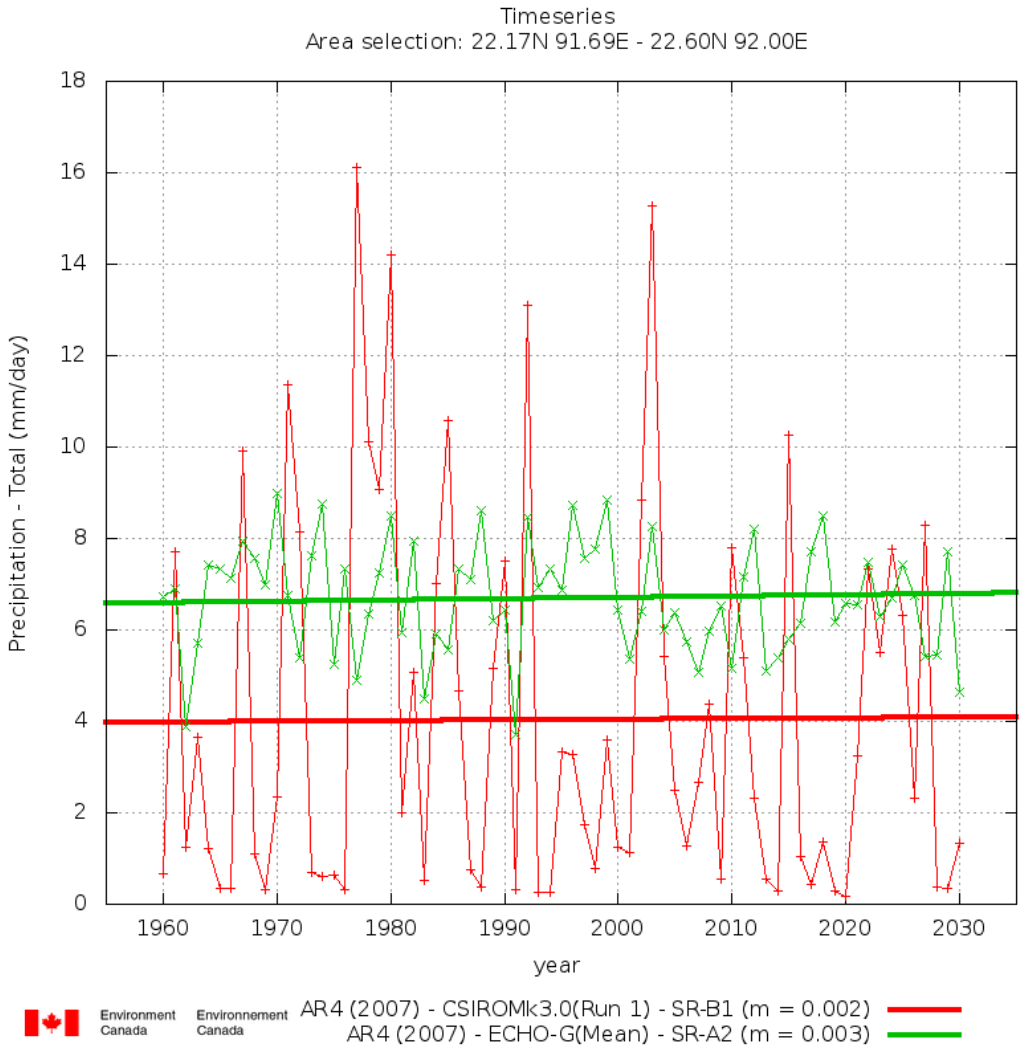


Figure 5. Trend-line Showing the Total Precipitation (mm/day) of CMA (1960-2030)

v. The simple daily intensity index (Precipitation>=1) is almost unchanged over the years.

vi. The number of heavy and very heavy precipitation days has increased (Approx. 5% for both R10 and R20).

vii. The number of days above 50mm precipitation (the threshold limit as defined in this project) is not changed in time.

viii. The number of consecutive dry days (rainfall<1mm) is increased by approx. 4.5%.

ix. The number of consecutive wet days (rainfall>=1mm) is decreased by approx. 2.5%.

x. The results obtained from RClimdex and CCDS are found the same.

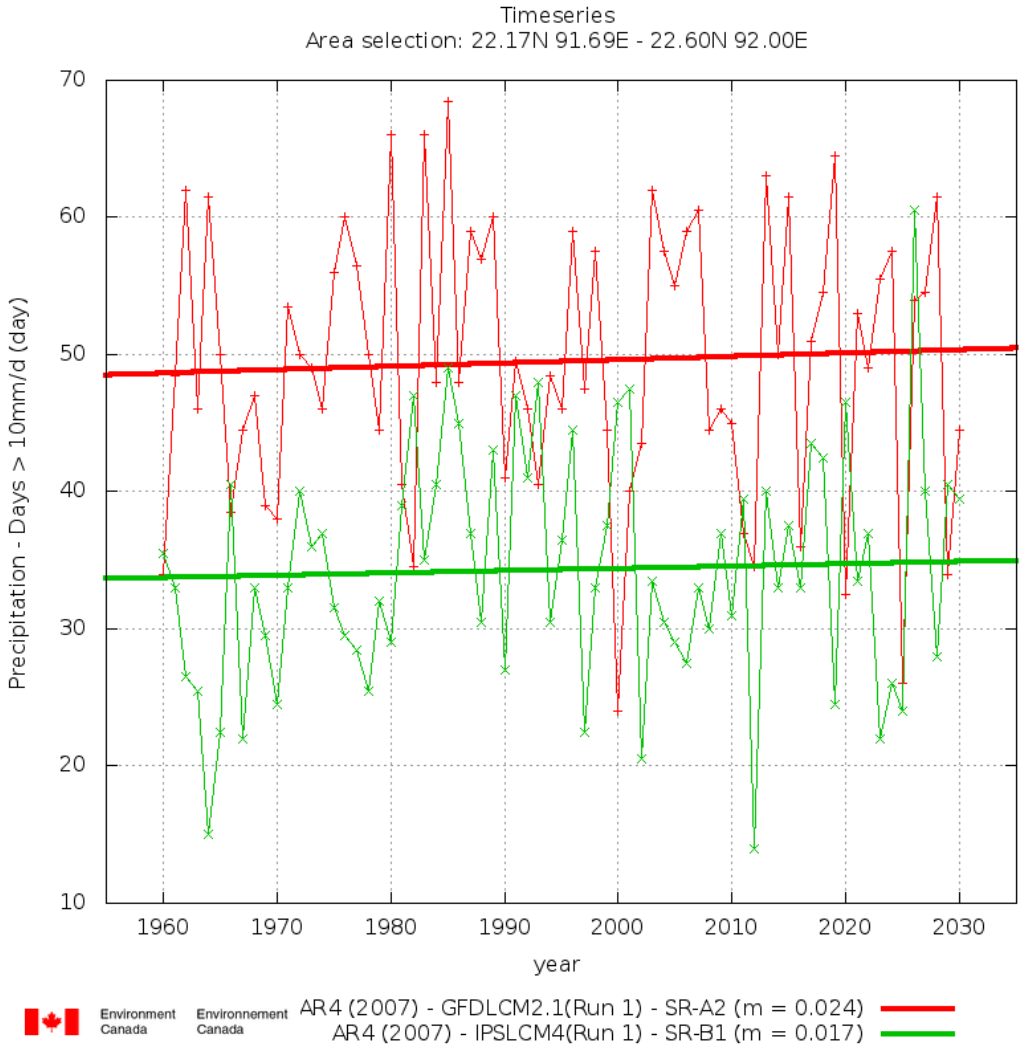


Figure 6. Trend-line Showing Precipitation Greater 10mm/day from 1960-2030

The projected future trends, as per the scenarios developed by IPCC and CCDS, are showing a slightly increasing trend for CMA (till 2030). This trend ranges from +0.1% - +0.4% (Figure 4-7).

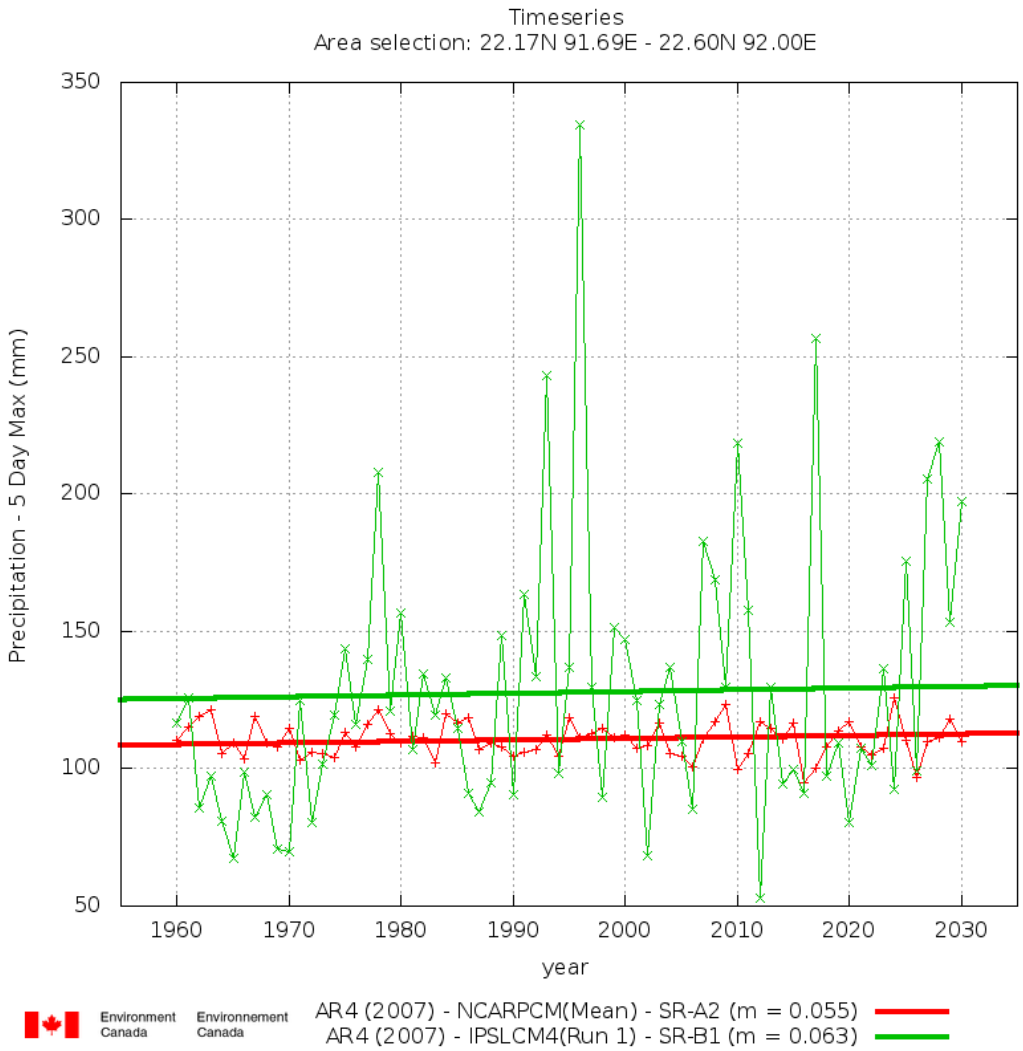


Figure 7. Trend-line Showing the Precipitation of 5-Day Maximum (mm) of CMA from 1960-2030

References

[1] Xuebin Zhang and Feng Yang. (2004). RClimDex (1.0): User Manual. Climate Research Branch, Environment Canada, Downsview, Ontario, Canada.

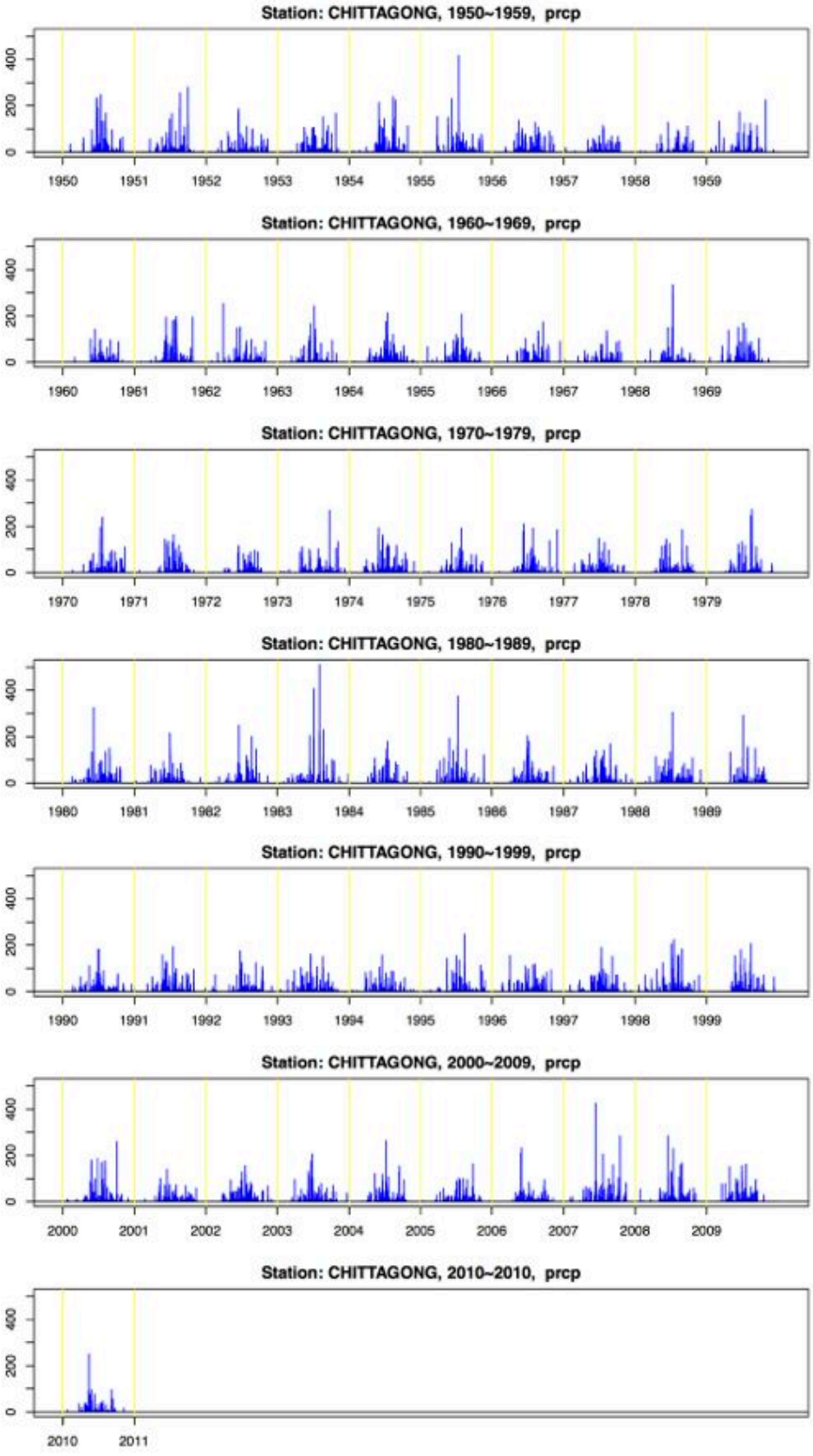
[2] Comprehensive Disaster Management Programme - II (CDMP-II). (2012). Landslide Inventory & Land-use Mapping, DEM Preparation, Precipitation Threshold Value & Establishment of Early Warning Devices. Ministry of Food and Disaster Management, Disaster Management and Relief Division, Government of the People's Republic of Bangladesh.

[3] Canadian Climate Data and Scenarios (CCDS). 2050s Ensemble Scenarios (1961-1990 baseline). Environment Canada, 10 Wellington, 23rd Floor, Gatineau QC, K1A 0H3, Canada. Retrieved from: http://www.cccsn.ec.gc.ca/?page=main&lang=en, accessed on 5 November 2014.

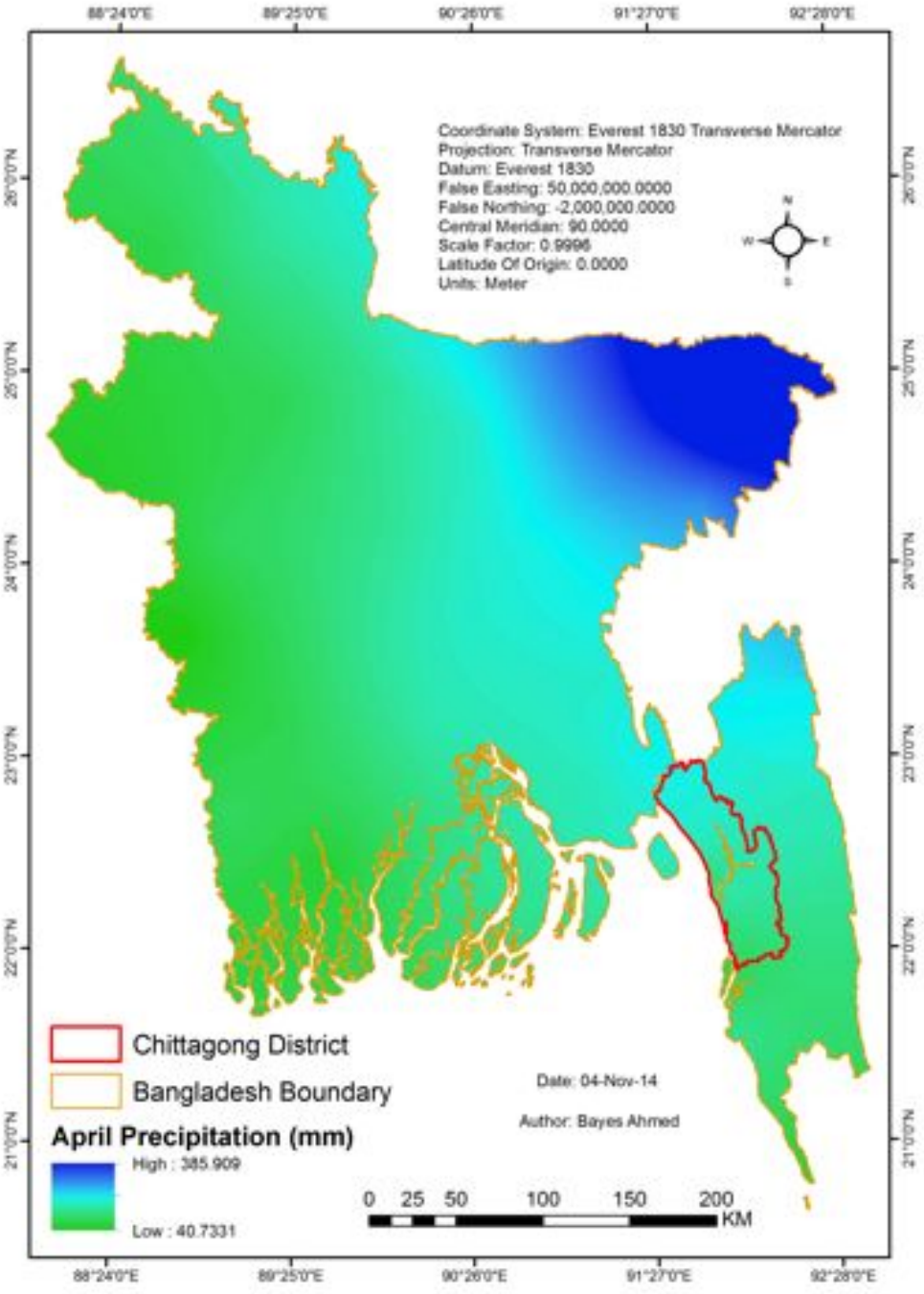
[4] Knutti, R., G. Abramowitz, M. Collins, V. Eyring, P.J. Gleckler, B. Hewitson, and L. Mearns, 2010: Good Practice Guidance Paper on Assessing and Combining Multi Model Climate Projections. In: Meeting Report of the Intergovernmental Panel on Climate Change Expert Meeting on Assessing and Combining Multi Model Climate Projections [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, and P.M. Midgley (eds.)]. IPCC Working Group I Technical Support Unit, University of Bern, Bern, Switzerland.

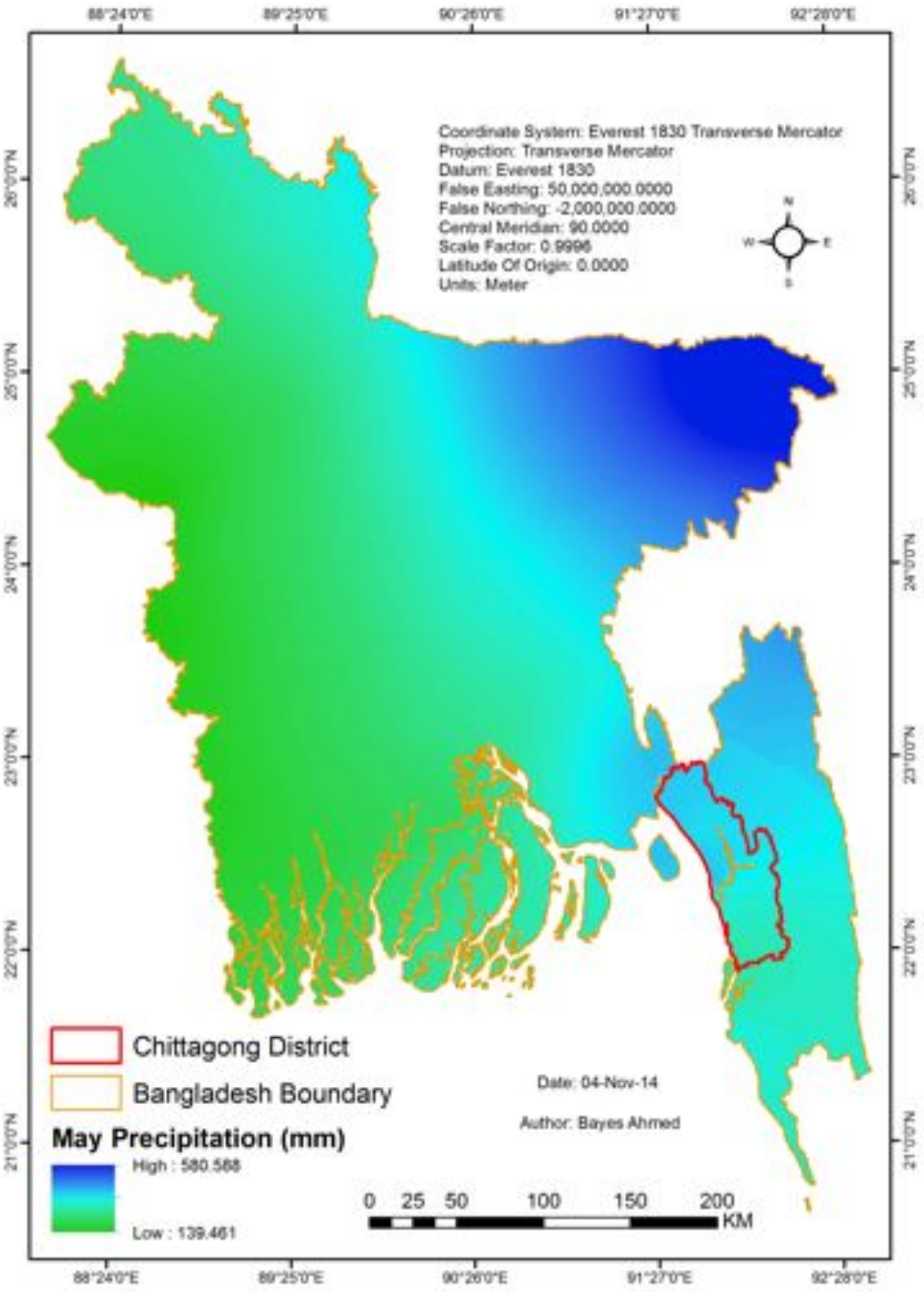
[5] IPCC (2001): Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change [Houghton, J.T., Ding, Y., Griggs, D.J., Noguer, M., van der Linden, P.J., Dai, X., Maskell, K. & Johnson, C.A. (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 881pp.

Appendix-I: Rainfall Pattern (mm) of Chittagong, Bangladesh (1950-2010)



Appendix-II: Rainfall Pattern Maps of Bangladesh during the Rainy Season

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21°0'0"N
Coordinate System: Everest 1830 Transverse Mercator
Projection: Transverse Mercator
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False Northing: -2,000,000.0000
Central Meridian: 90.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Meter
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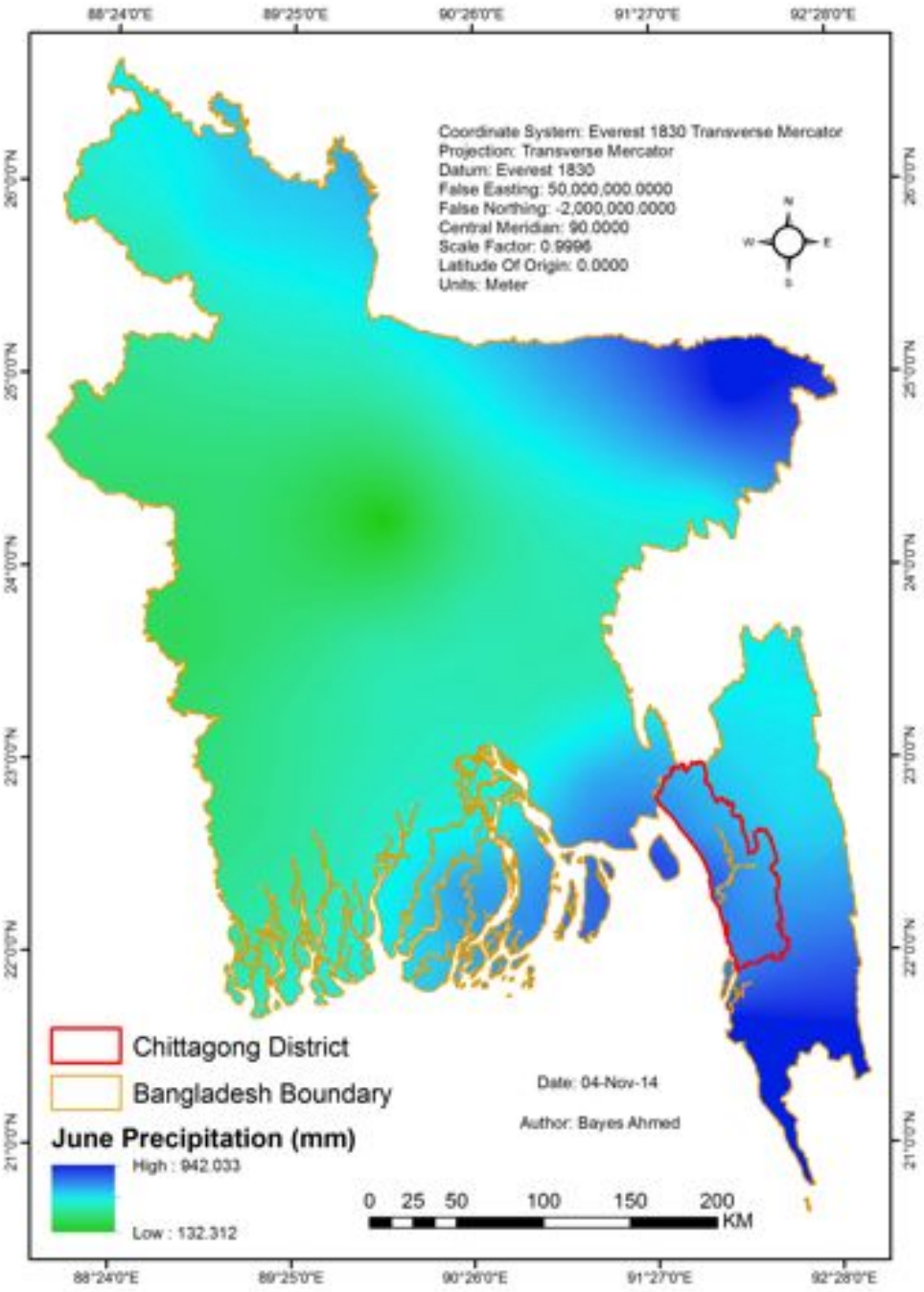
Chittagong District
Bangladesh Boundary
May Precipitation (mm)
High : 580.588
Low : 139.461
Date: 04-Nov-14
Author: Bayes Ahmed
0 25 50 100 150 200
KM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Coordinate System: Everest 1830 Transverse Mercator
Projection: Transverse Mercator
Datum: Everest 1830
False Easting: 50,000,000.0000
False Northing: -2,000,000.0000
Central Meridian: 90.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Meter
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Chittagong District
Bangladesh Boundary
June Precipitation (mm)
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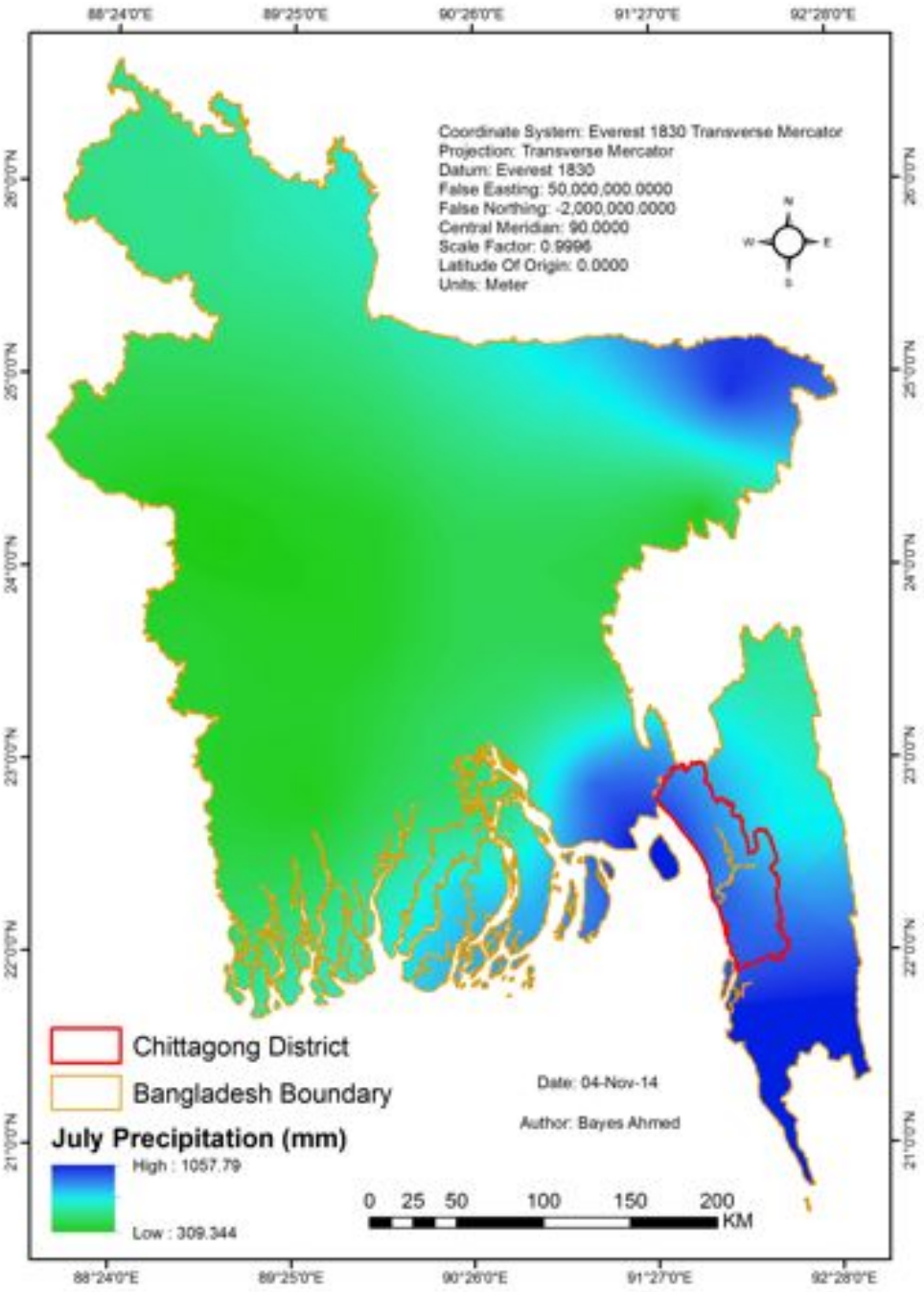
Low : 132.312
Date: 04-Nov-14
Author: Bayes Ahmed
0 25 50 100 150 200
KM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Coordinate System: Everest 1830 Transverse Mercator
Projection: Transverse Mercator
Datum: Everest 1830
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False Northing: -2,000,000.0000
Central Meridian: 90.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Meter
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Chittagong District
Bangladesh Boundary
July Precipitation (mm)
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Low : 309.344
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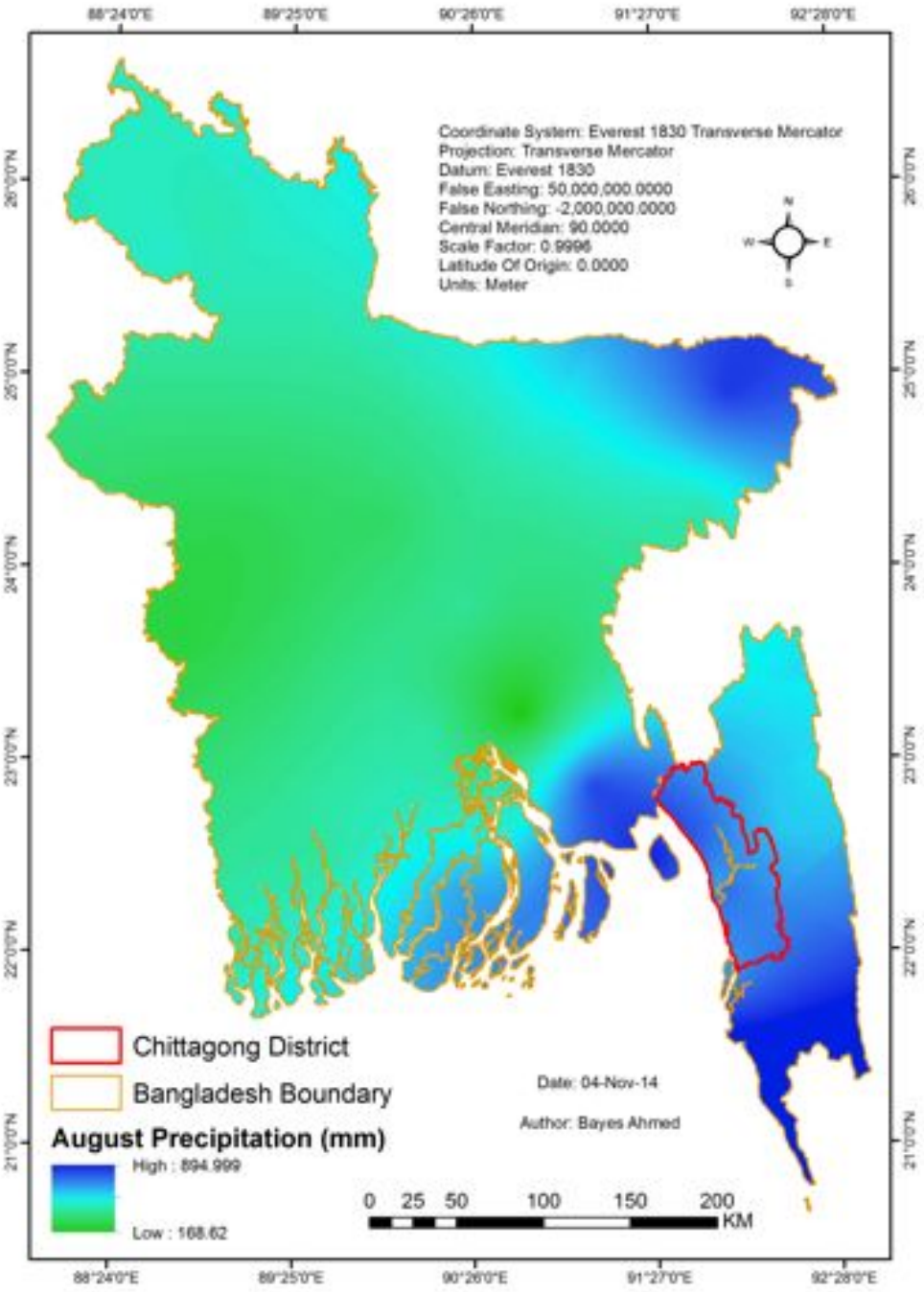
Author: Bayes Ahmed
0 25 50 100 150 200
KM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Projection: Transverse Mercator
Datum: Everest 1830
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False Northing: -2,000,000.0000
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Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Meter
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Chittagong District
Bangladesh Boundary
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Low : 168.62
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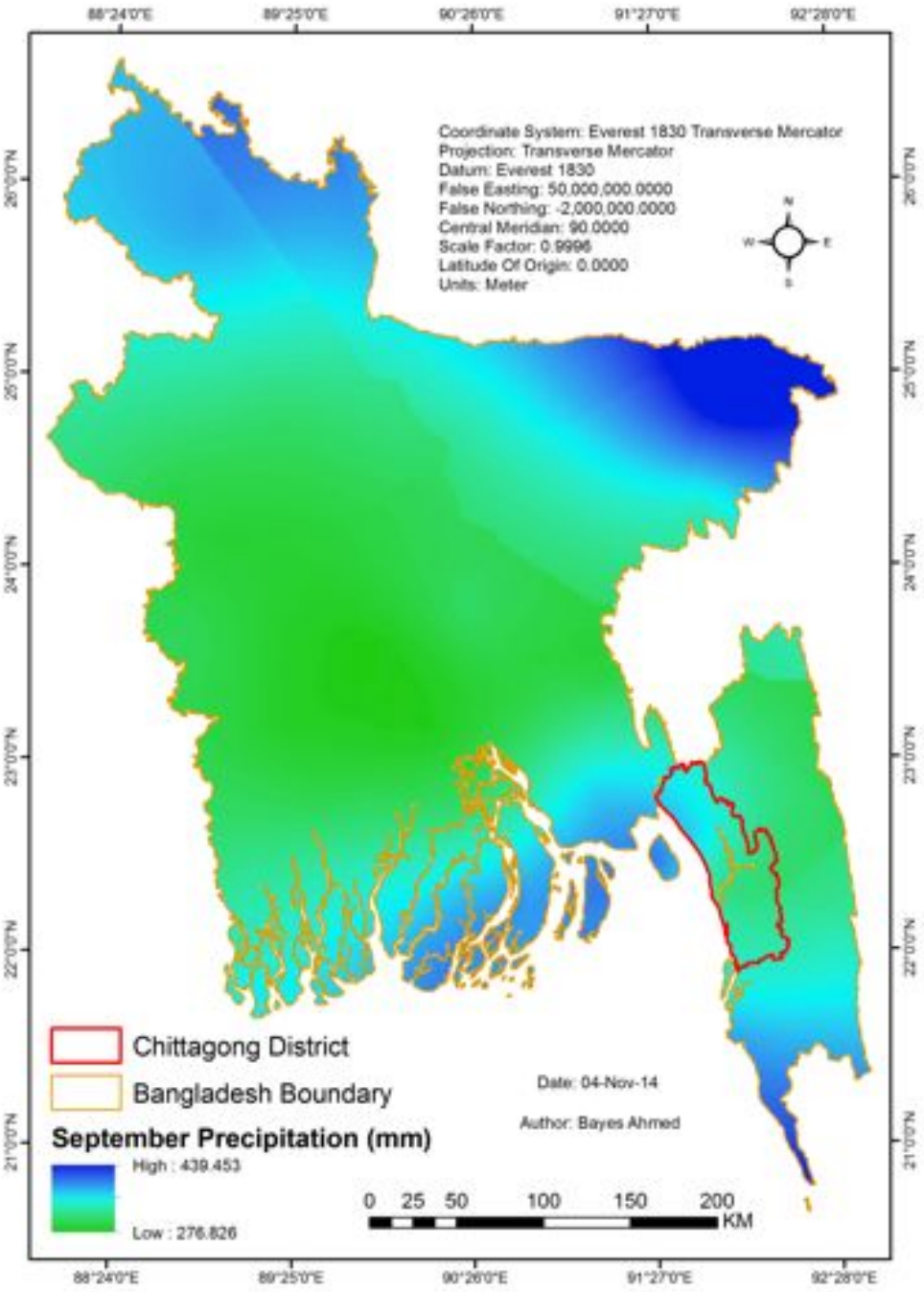
Author: Bayes Ahmed
0 25 50 100 150 200
KM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Units: Meter
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Chittagong District
Bangladesh Boundary
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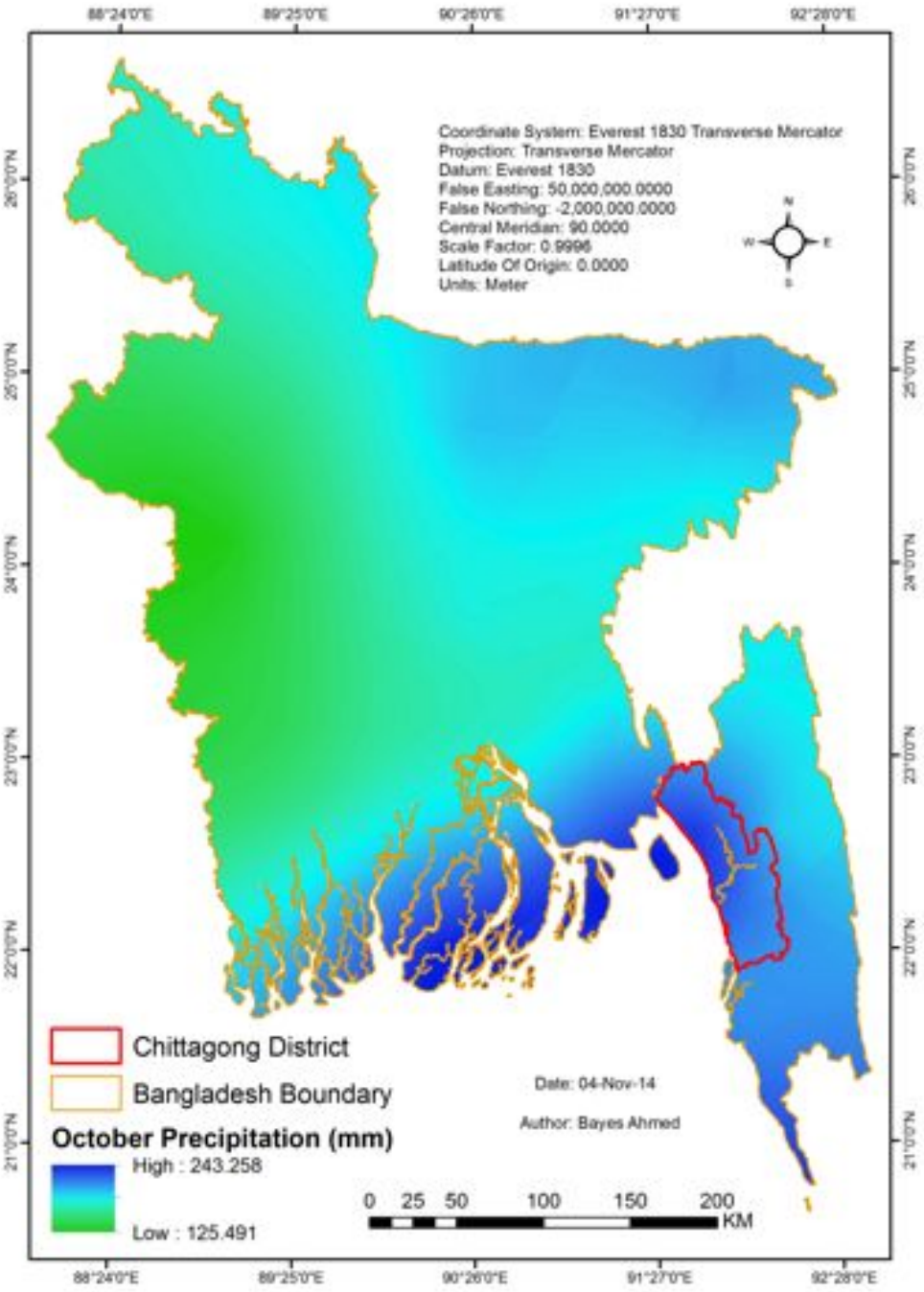
Author: Bayes Ahmed
September Precipitation (mm)
High : 439.453
Low : 276.826
0 25 50 100 150 200
KM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Projection: Transverse Mercator
Datum: Everest 1830
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False Northing: -2,000,000.0000
Central Meridian: 90.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Meter
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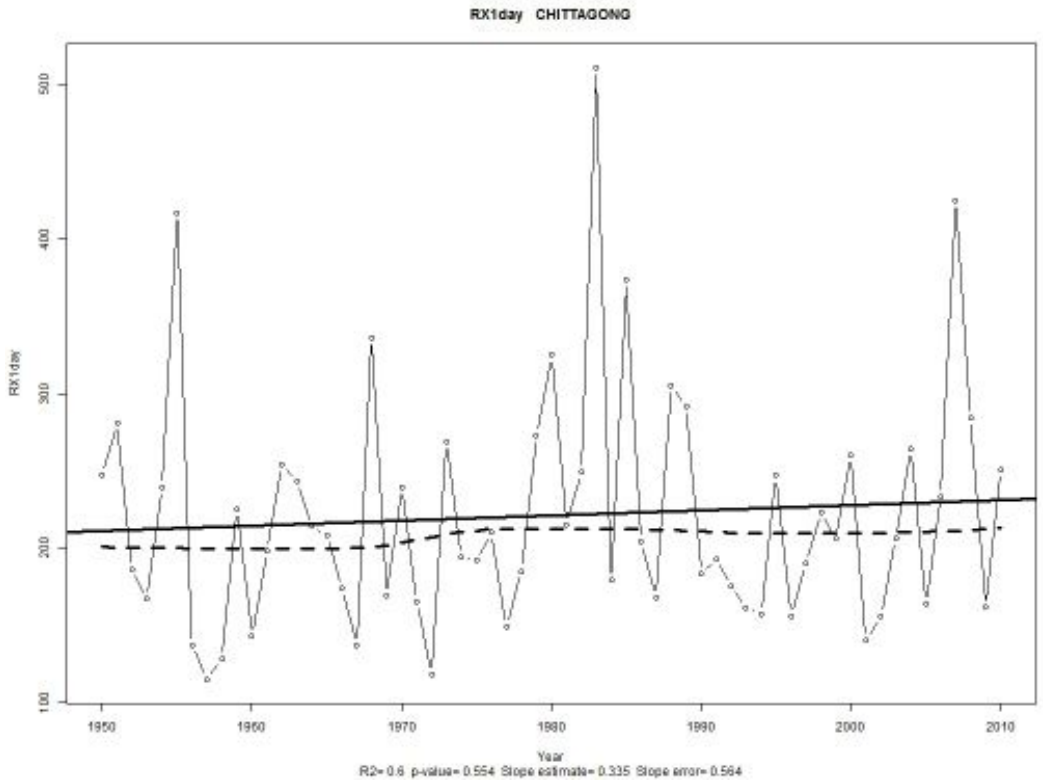
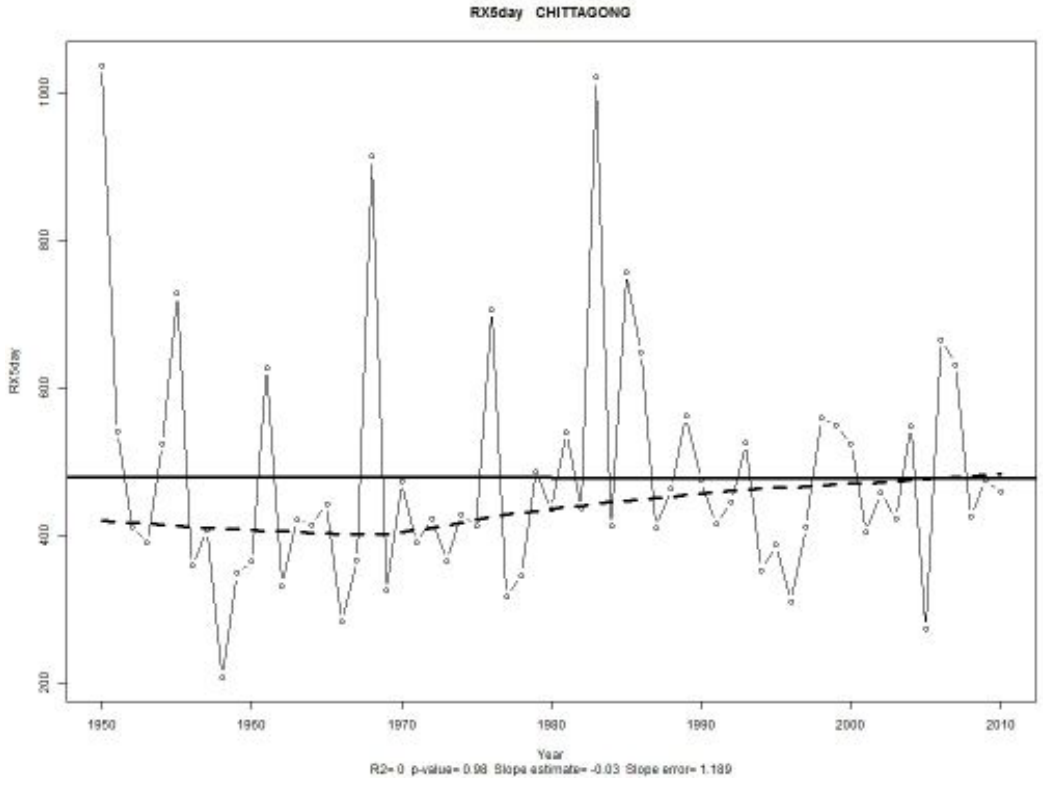
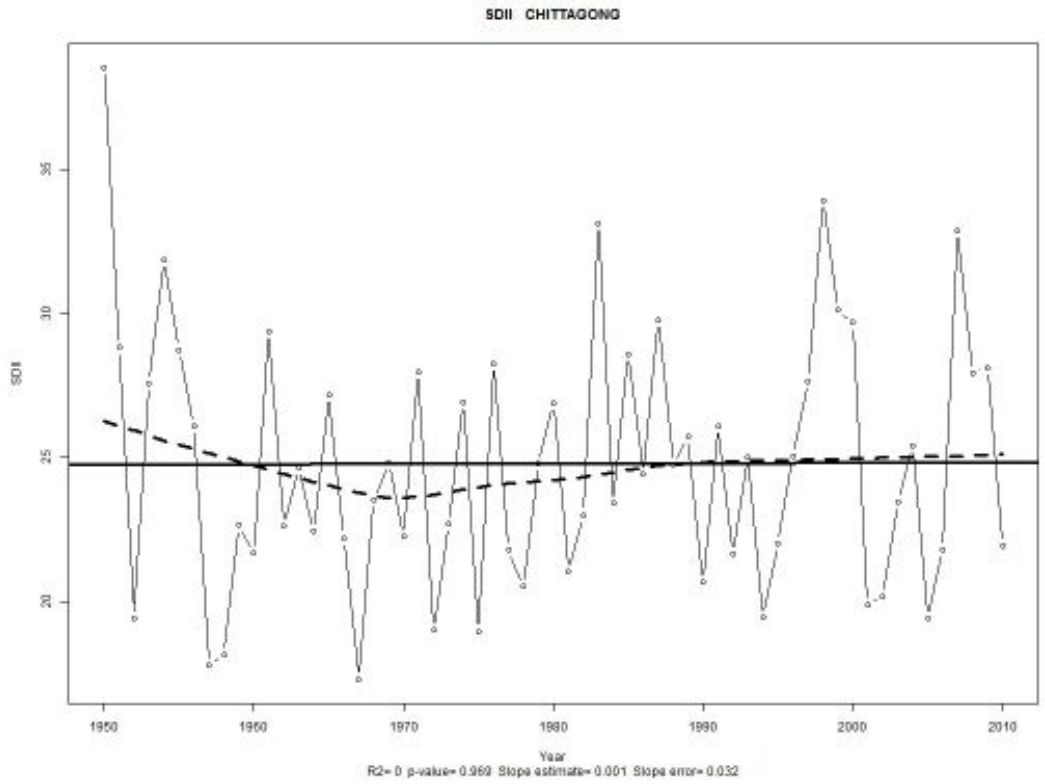
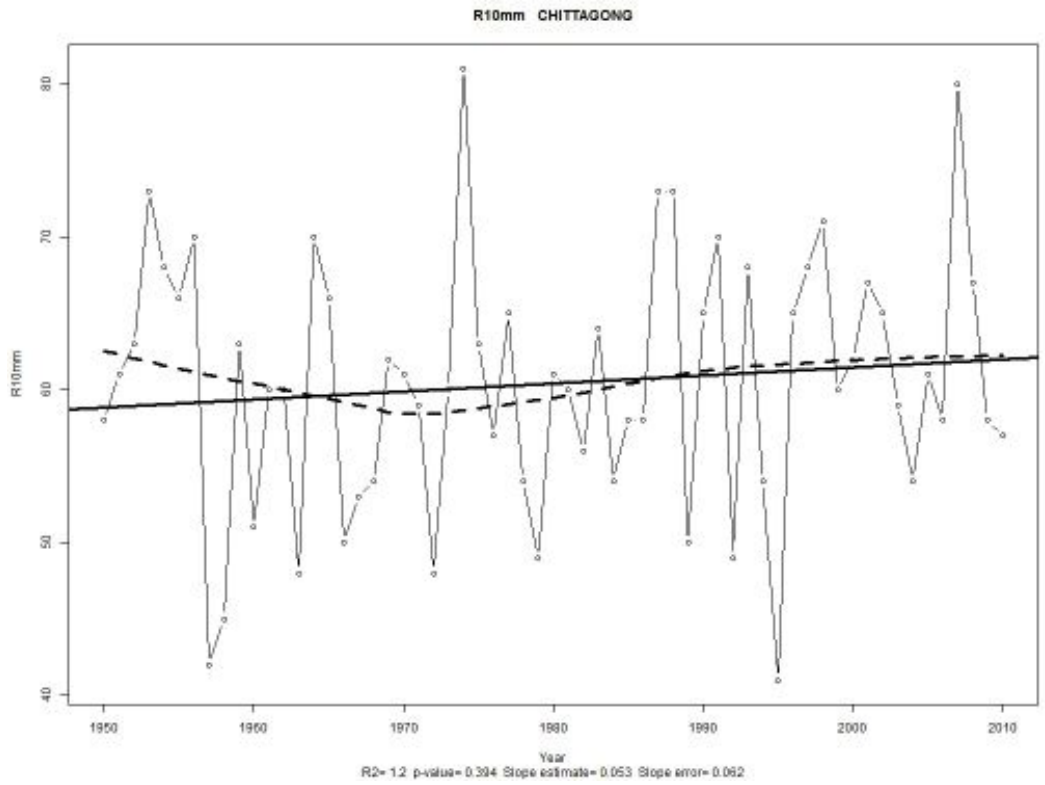
Chittagong District
Bangladesh Boundary
October Precipitation (mm)
High : 243.258
Low : 125.491
Date: 04-Nov-14
Author: Bayes Ahmed
0 25 50 100 150 200
KM

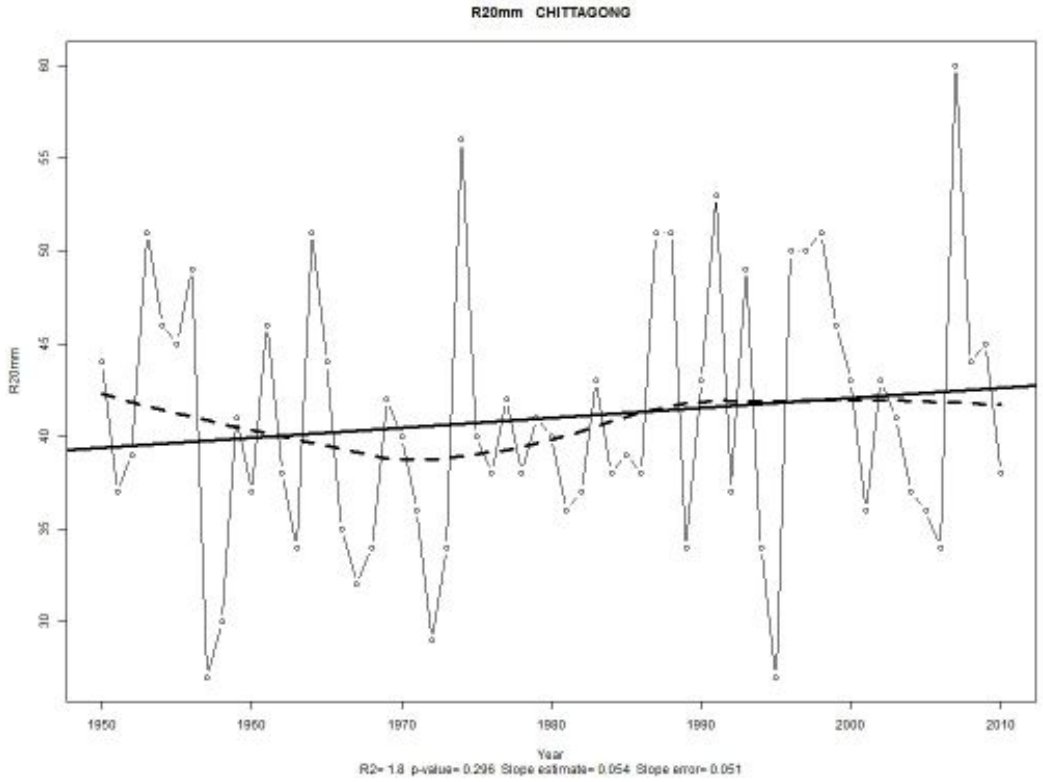
Appendix-III: Plots Generated for the Rainfall Indices

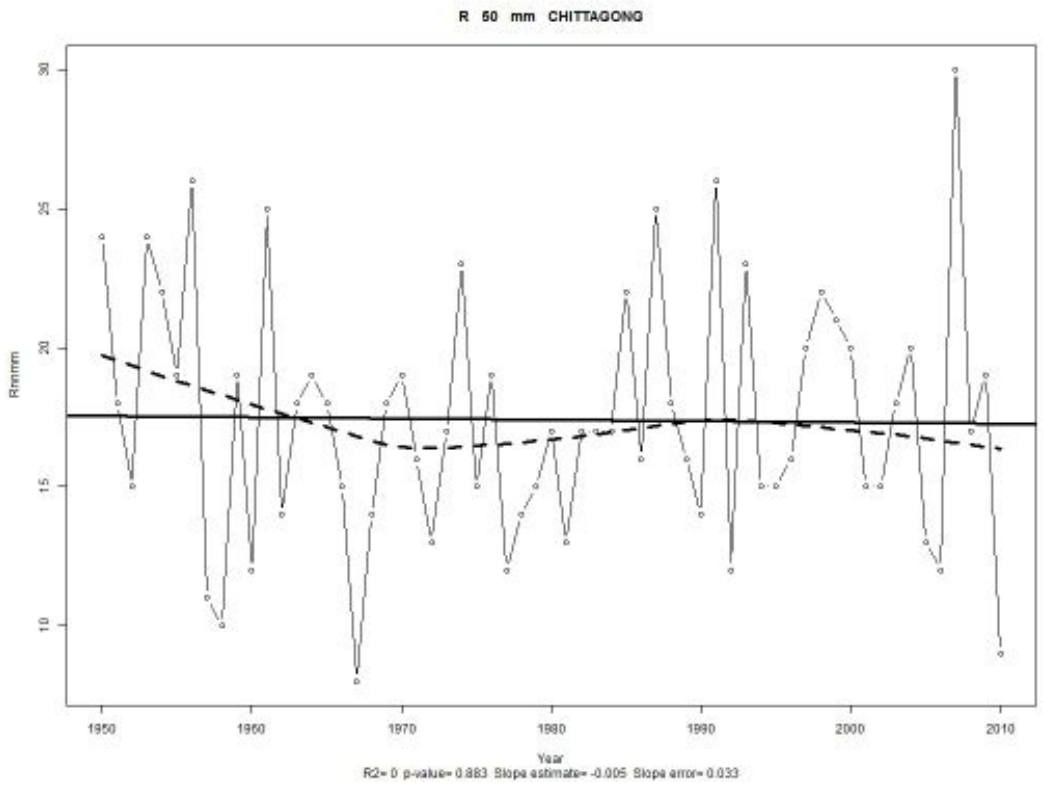


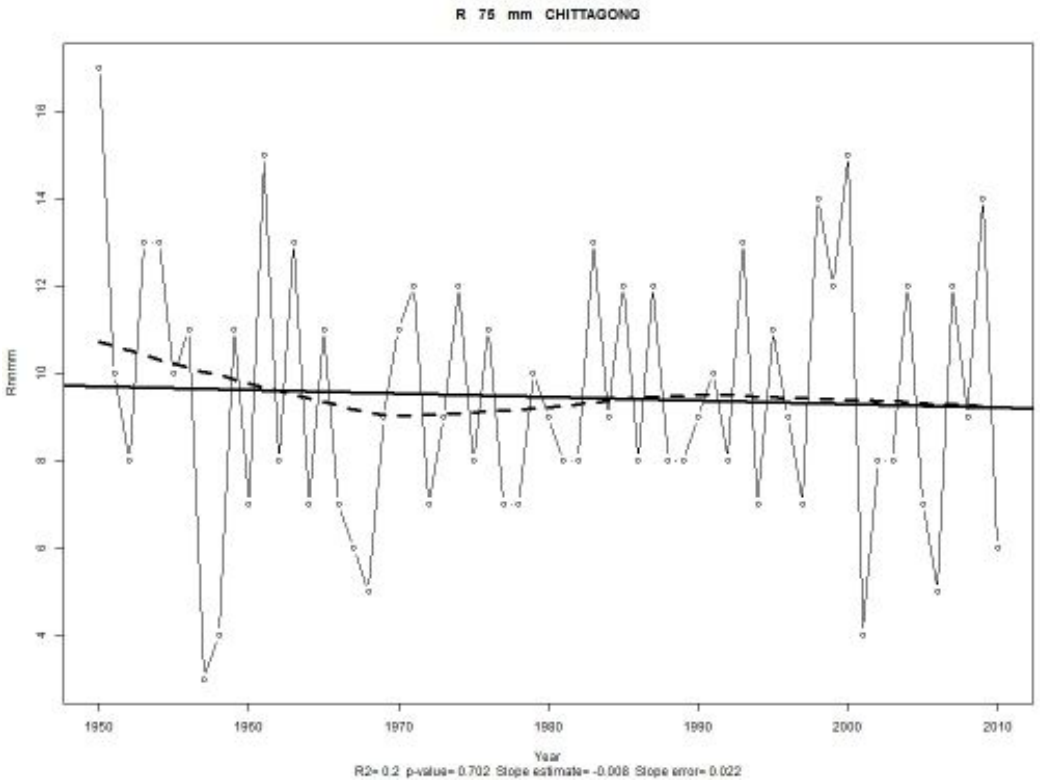


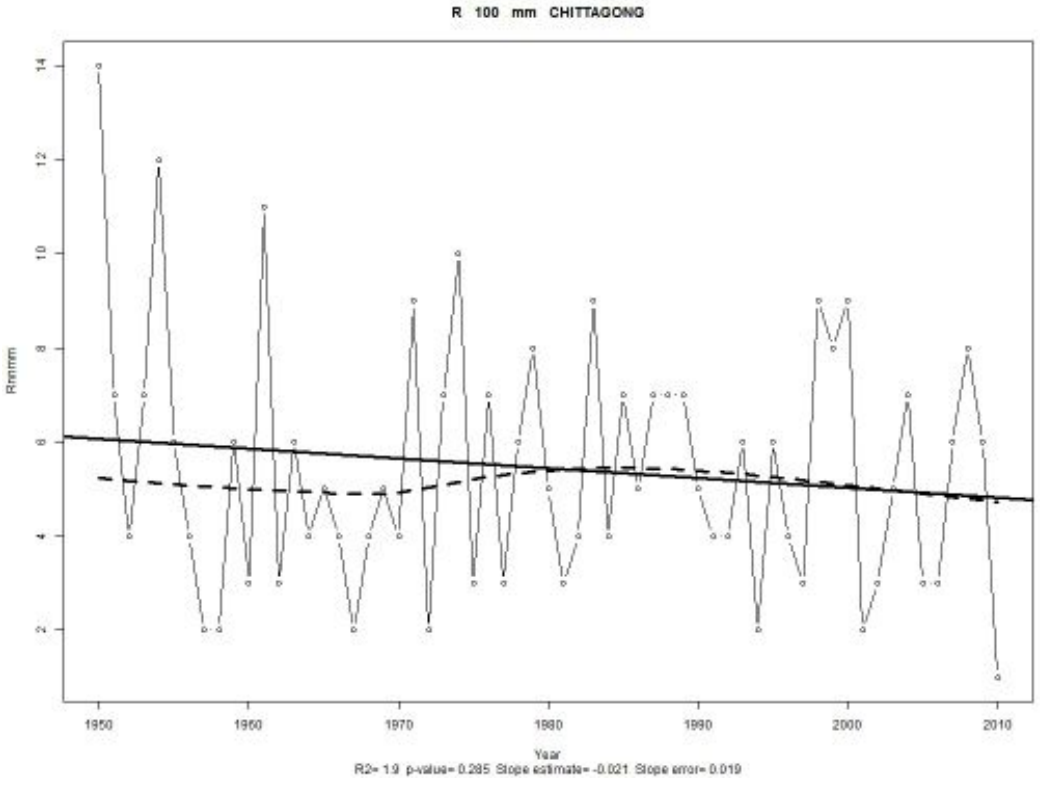

SDII CHITTAGONG
SDII
Year
R2= 0 p-value= 0.969 Slope estimate= 0.001 Slope error= 0.032

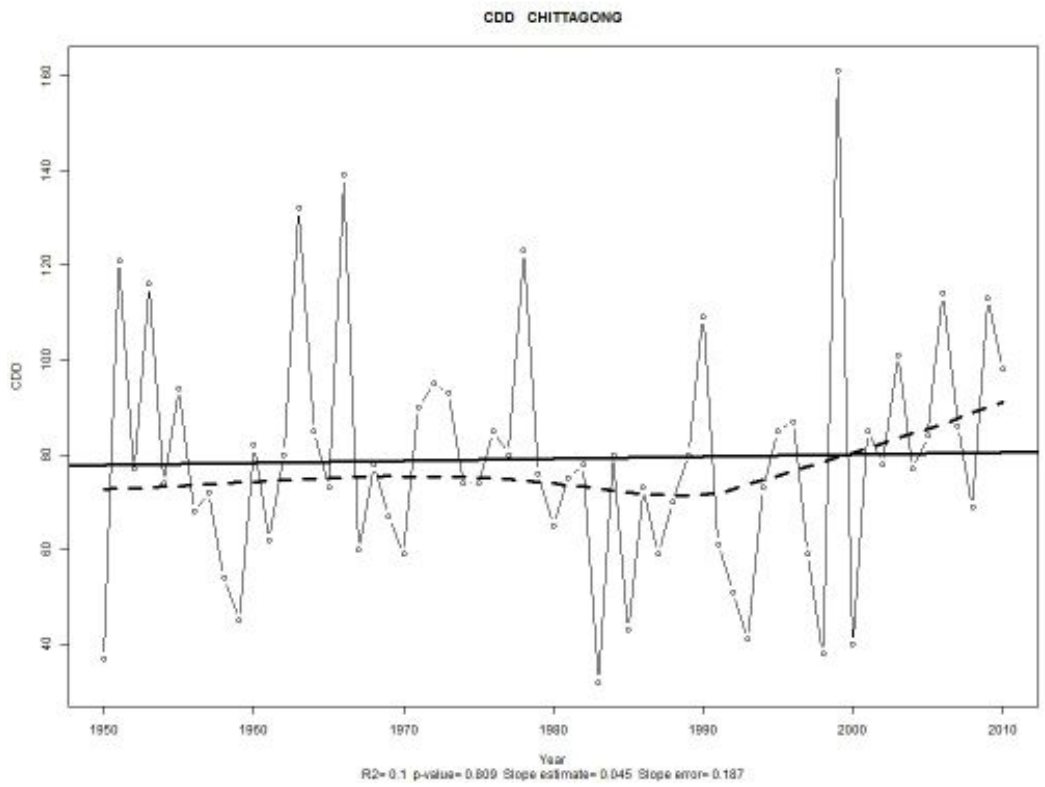

R10mm CHITTAGONG
R10mm
Year
R2= 1.2 p-value= 0.394 Slope estimate= 0.053 Slope error= 0.062

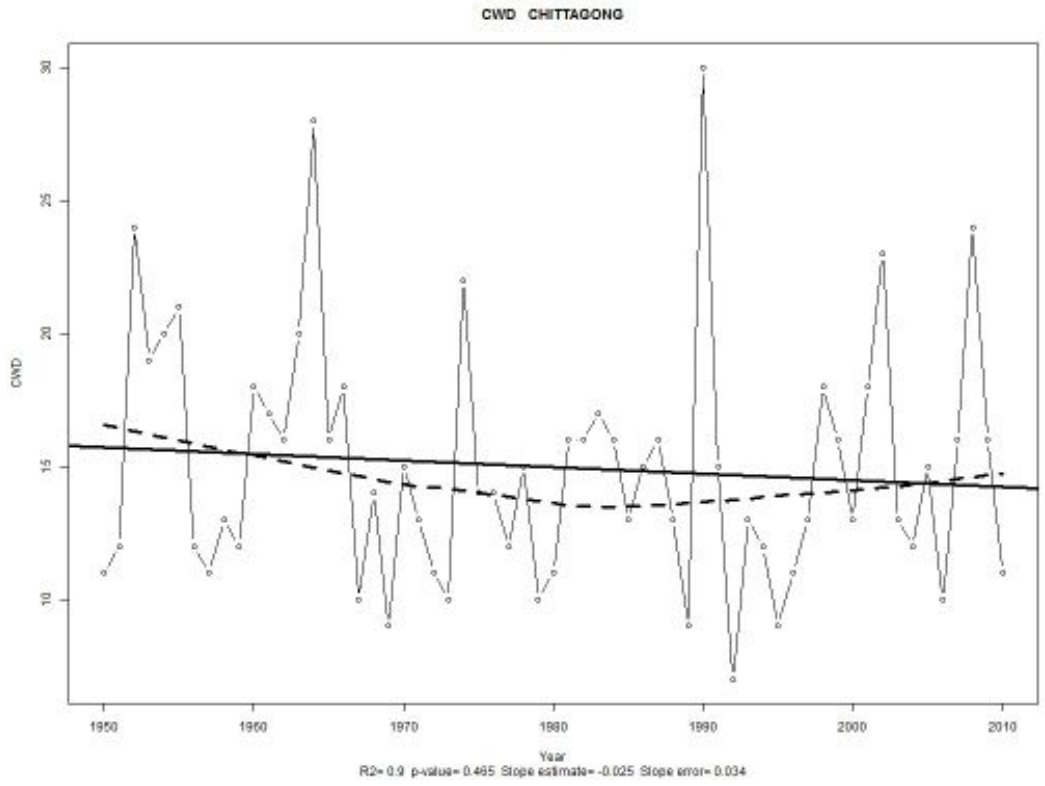

R20mm CHITTAGONG
R20mm
Year
R2= 1.8 p-value= 0.296 Slope estimate= 0.054 Slope error= 0.051

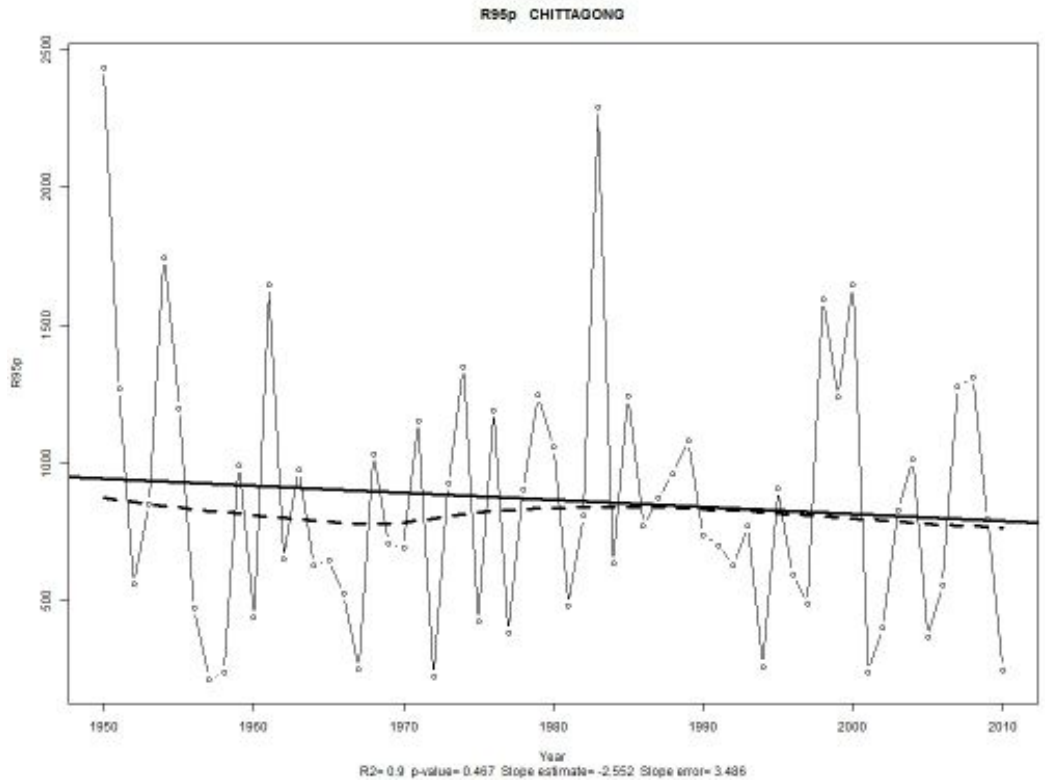

R 50 mm CHITTAGONG
Rnnmm
Year
R2= 0 p-value= 0.883 Slope estimate= -0.005 Slope error= 0.033

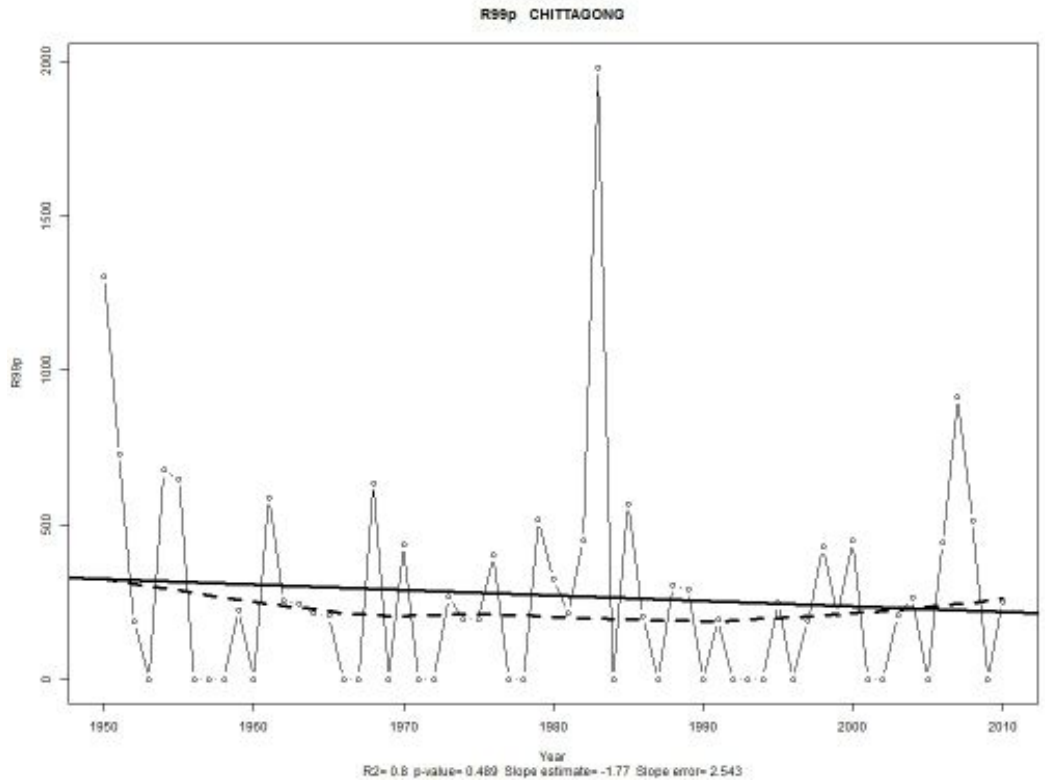

R 75 mm CHITTAGONG
Rnnmm
Year
R2= 0.2 p-value= 0.702 Slope estimate= -0.008 Slope error= 0.022

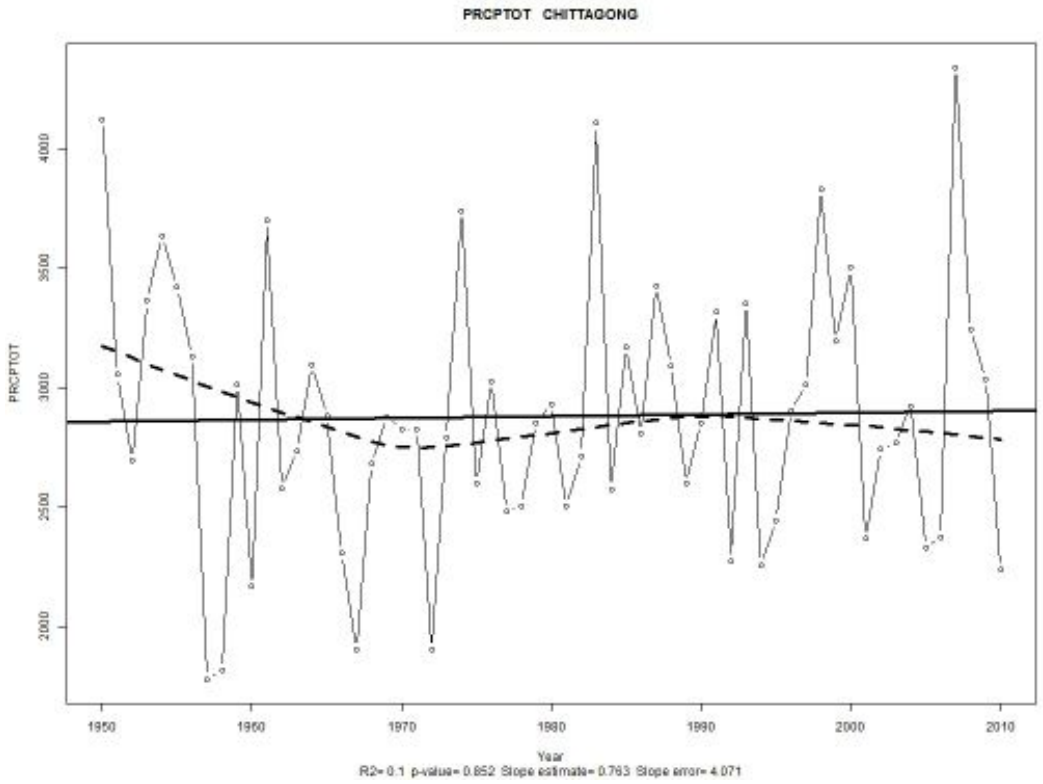

R 100 mm CHITTAGONG
Rnnmm
Year
R2= 1.9 p-value= 0.285 Slope estimate= -0.021 Slope error= 0.019


CDD CHITTAGONG
CDD
Year
R2= 0.1 p-value= 0.809 Slope estimate= 0.045 Slope error= 0.187


CWD CHITTAGONG
CWD
Year
R2= 0.9 p-value= 0.465 Slope estimate= -0.025 Slope error= 0.034


R95p CHITTAGONG
R95p
2500
2000
1500
1000
500
1950
1960
1970
1980
1990
2000
2010
Year
R2= 0.9 p-value= 0.467 Slope estimate= -2.552 Slope error= 3.486


R99p CHITTAGONG
R99p
2000
1500
1000
500
0
1950
1960
1970
1980
1990
2000
2010
Year
R2= 0.8 p-value= 0.489 Slope estimate= -1.77 Slope error= 2.543



Appendix-IV: Year-wise Rainfall Indices of Chittagong (1950-2010)

Year	CDD	CWD	PrcpTot	R10	R20	R50	R75	R100	R95p	R99p	SDII
1950	37	11	4124	58	44	24	17	14	2434	1304	38.5
1951	121	12	3055	61	37	18	10	7	1269	728	28.8
1952	77	24	2697	63	39	15	8	4	562	186	19.4
1953	116	19	3364	73	51	24	13	7	852	0	27.6
1954	74	20	3635	68	46	22	13	12	1746	677	31.9
1955	94	21	3421	66	45	19	10	6	1199	648	28.7
1956	68	12	3132	70	49	26	11	4	475	0	26.1
1957	72	11	1780	42	27	11	3	2	217	0	17.8
1958	54	13	1817	45	30	10	4	2	240	0	18.2
1959	45	12	3013	63	41	19	11	6	993	225	22.7
1960	82	18	2169	51	37	12	7	3	442	0	21.7
1961	62	17	3702	60	46	25	15	11	1646	588	29.4
1962	80	16	2579	60	38	14	8	3	653	254	22.6
1963	132	20	2737	48	34	18	13	6	975	243	24.7
1964	85	28	3096	70	51	19	7	4	630	214	22.4
1965	73	16	2882	66	44	18	11	5	649	208	27.2
1966	139	18	2310	50	35	15	7	4	527	0	22.2
1967	60	10	1904	53	32	8	6	2	253	0	17.3
1968	78	14	2683	54	34	14	5	4	1032	634	23.5
1969	67	9	2879	62	42	18	9	5	708	0	24.8

1970	59	15	2828	61	40	19	11	4	694	435	22.3
1971	90	13	2827	59	36	16	12	9	1153	0	28
1972	95	11	1903	48	29	13	7	2	225	0	19
1973	93	10	2791	60	34	17	9	7	927	269	22.7
1974	74	22	3741	81	56	23	12	10	1350	194	26.9
1975	74	14	2598	63	40	15	8	3	426	192	19
1976	85	14	3025	57	38	19	11	7	1192	402	28.3
1977	80	12	2484	65	42	12	7	3	384	0	21.8
1978	123	15	2505	54	38	14	7	6	904	0	20.5
1979	76	10	2851	49	41	15	10	8	1246	518	24.8
1980	65	11	2932	61	40	17	9	5	1058	325	26.9
1981	75	16	2505	60	36	13	8	3	481	215	21.1
1982	78	16	2715	56	37	17	8	4	810	450	23
1983	32	17	4108	64	43	17	13	9	2293	1980	33.1
1984	80	16	2576	54	38	17	9	4	636	0	23.4
1985	43	13	3172	58	39	22	12	7	1242	568	28.6
1986	73	15	2810	58	38	16	8	5	773	204	24.4
1987	59	16	3426	73	51	25	12	7	876	0	29.8
1988	70	13	3093	73	51	18	8	7	962	305	24.7
1989	80	9	2598	50	34	16	8	7	1083	292	25.7
1990	109	30	2852	65	43	14	9	5	740	0	20.7
1991	61	15	3316	70	53	26	10	4	703	193	26.1
1992	51	7	2275	49	37	12	8	4	629	0	21.7
1993	41	13	3352	68	49	23	13	6	773	0	25
1994	73	12	2258	54	34	15	7	2	262	0	19.5
1995	85	9	2444	41	27	15	11	6	910	247	22
1996	87	11	2904	65	50	16	9	4	596	0	25
1997	59	13	3015	68	50	20	7	3	490	190	27.7
1998	38	18	3833	71	51	22	14	9	1596	428	33.9
1999	161	16	3194	60	46	21	12	8	1241	206	30.1
2000	40	13	3503	62	43	20	15	9	1645	448	29.7
2001	85	18	2368	67	36	15	4	2	241	0	19.9
2002	78	23	2745	65	43	15	8	3	404	0	20.2
2003	101	13	2769	59	41	18	8	5	830	206	23.5
2004	77	12	2924	54	37	20	12	7	1013	264	25.4
2005	84	15	2331	61	36	13	7	3	368	0	19.4
2006	114	10	2375	58	34	12	5	3	559	443	21.8
2007	86	16	4340	80	60	30	12	6	1279	915	32.9
2008	69	24	3241.9	67	44	17	9	8	1311.2	513.1	27.9
2009	113	16	3037.3	58	45	19	14	6	799.4	0	28.1
2010	98	11	2238.7	57	38	9	6	1	250.9	250.9	21.9

Appendix-V: Year and Month-wise 'Rx1 Day' Index Values of Chittagong (1950-2010)

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1950	0	34	2	61	96	233	247	168	96	56	65	0	247
1951	0	0	56	40	64	84	166	256	109	281	0	5	281
1952	0	0	50	88	49	186	110	100	26	76	56	0	186
1953	0	0	5	38	106	104	106	152	113	167	15	0	167
1954	7	8	22	4	42	214	144	239	61	113	0	1	239
1955	0	0	153	27	150	231	417	83	77	59	77	0	417
1956	1	0	23	48	137	102	67	128	83	89	69	0	137
1957	19	6	0	0	59	70	115	53	69	67	0	1	115
1958	6	4	0	36	74	128	63	95	112	49	0	1	128
1959	15	27	133	1	33	173	124	124	115	225	0	10	225
1960	0	0	21	0	101	143	101	97	38	89	0	2	143
1961	0	3	8	25	44	195	182	198	30	195	1	0	198
1962	6	42	254	28	62	152	94	99	67	92	0	0	254
1963	0	0	27	21	73	167	243	83	44	96	0	0	243
1964	3	1	0	61	41	94	214	121	47	73	9	0	214
1965	0	68	20	5	83	121	208	105	56	44	0	0	208
1966	0	0	28	0	62	104	79	135	174	76	0	91	174
1967	12	0	25	52	34	47	80	137	85	93	0	0	137
1968	5	11	55	5	52	150	336	63	16	39	0	0	336
1969	20	0	71	138	34	151	169	90	104	15	16	0	169
1970	1	10	1	35	50	82	239	85	96	61	110	0	239
1971	9	0	0	2	29	144	165	119	43	16	0	0	165
1972	0	1	0	21	15	118	80	89	96	20	0	0	118
1973	5	5	14	88	110	100	102	63	269	105	134	18	269

1974	7	0	54	25	68	194	126	119	109	85	48	0	194
1975	0	5	0	28	54	129	192	92	78	77	47	0	192
1976	0	5	1	22	26	210	192	71	27	139	185	10	210
1977	0	38	0	54	81	149	131	96	38	31	32	0	149
1978	0	0	1	18	114	145	33	185	116	39	0	0	185
1979	1	1	1	27	53	135	119	273	112	56	38	23	273
1980	0	26	14	22	133	325	97	150	42	69	0	0	325
1981	8	2	75	61	93	61	215	85	50	10	1	23	215
1982	0	4	26	41	10	249	118	201	145	2	30	1	249
1983	5	21	39	35	41	205	407	511	79	101	26	38	511
1984	1	0	0	43	107	76	179	89	77	48	0	2	179
1985	10	6	57	95	194	139	374	144	41	23	121	2	374
1986	2	0	0	65	37	204	179	60	43	49	72	0	204
1987	3	13	30	81	26	139	140	168	75	16	37	16	168
1988	0	6	27	113	100	133	305	68	84	108	56	1	305
1989	0	2	0	132	35	68	292	23	148	68	14	0	292
1990	0	25	19	63	111	183	182	23	25	76	35	32	183
1991	12	0	33	63	159	130	193	99	80	70	95	13	193
1992	0	72	0	1	28	175	125	72	124	108	3	24	175
1993	9	51	91	24	103	161	107	151	79	41	8	0	161
1994	7	6	82	88	58	157	80	87	41	59	11	0	157
1995	0	6	8	18	143	90	155	247	43	16	113	0	247
1996	0	38	49	156	48	110	115	118	68	94	3	1	156
1997	0	27	48	16	69	71	190	79	152	71	38	4	190
1998	28	71	54	96	124	37	223	183	38	48	70	0	223
1999	0	0	0	0	154	180	141	206	60	71	2	62	206

2000	10	0	9	27	180	188	171	177	33	260	15	0	260
2001	0	12	1	23	101	140	75	74	70	42	59	0	140
2002	1	0	36	31	94	94	156	85	36	49	69	10	156
2003	0	0	20	97	55	206	64	80	60	71	0	37	206
2004	0	0	3	41	122	119	264	41	154	95	0	0	264
2005	5	0	29	58	26	50	103	101	164	31	18	5	164
2006	0	0	0	40	233	54	84	23	95	28	15	0	233
2007	0	21	4	66	61	425	206	100	160	284	82	0	425
2008	54.7	4.8	9.5	1.1	58.8	284.1	229	167.2	39	60.4	34.8	0	284.1
2009	0	1.8	77.7	151.1	100.4	155.2	162	64.8	96	28.6	0	0	162
2010	8.8	0	36	38.2	250.9	76.6	47.4	31	95.4	3.6	17.3	1	250.9

Appendix-VI: Year and Month-wise 'Rx5 Day' Index Values of Chittagong (1950-2010)

Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1950	0	43	2	101	172	1037	504	384	142	130	92	0	1037
1951	0	0	69	127	103	264	361	541	144	455	7	7	541
1952	0	0	50	157	80	412	246	272	69	184	118	0	412
1953	0	0	5	57	241	213	313	390	302	198	17	0	390
1954	7	14	26	26	110	524	224	472	93	146	0	1	524
1955	0	0	254	184	300	310	728	175	84	145	223	0	728
1956	1	0	32	72	208	359	132	290	244	137	88	0	359
1957	35	6	6	0	76	92	407	116	125	86	0	1	407
1958	6	6	0	37	85	203	181	198	208	87	0	1	208
1959	18	52	236	60	82	264	349	323	184	249	249	17	349
1960	0	0	23	0	114	346	365	146	147	172	11	2	365
1961	0	5	12	35	82	519	481	627	76	217	2	0	627

1962	6	42	254	254	171	332	300	168	118	133	130	0	332
1963	0	0	27	23	96	422	420	193	66	157	3	0	422
1964	3	2	1	166	76	191	415	243	154	147	10	0	415
1965	0	71	20	5	100	262	440	443	150	83	17	0	443
1966	0	0	28	0	99	203	137	280	283	177	0	99	283
1967	14	0	25	99	77	89	158	366	173	156	0	0	366
1968	7	11	58	5	138	344	914	143	52	65	16	0	914
1969	20	0	113	224	62	278	325	237	189	22	31	0	325
1970	1	20	1	35	80	176	473	140	168	156	125	0	473
1971	10	1	0	2	39	379	391	271	171	47	11	0	391
1972	0	2	0	36	15	423	200	166	136	60	0	0	423
1973	5	5	14	142	302	276	305	296	365	159	212	40	365
1974	7	0	85	107	163	429	287	250	361	133	61	61	429
1975	0	5	0	43	170	210	413	164	129	206	86	0	413
1976	0	6	1	28	71	706	413	228	43	160	228	228	706
1977	0	71	46	170	93	279	317	226	56	82	41	0	317
1978	0	0	2	34	151	346	100	284	335	72	8	0	346
1979	1	2	1	27	128	259	325	486	255	59	47	81	486
1980	0	26	25	32	170	435	277	324	138	179	0	0	435
1981	15	2	118	170	158	145	540	186	93	21	1	36	540
1982	0	7	52	73	25	437	255	334	241	85	43	1	437
1983	5	42	55	141	120	439	684	1021	94	193	45	52	1021
1984	38	0	0	82	251	273	413	129	159	63	0	2	413
1985	17	6	88	95	294	224	757	256	91	50	198	2	757
1986	2	0	0	81	60	560	648	118	94	99	122	0	648
1987	3	20	52	182	29	225	393	410	271	63	49	17	410

1988	0	11	30	178	131	285	464	137	167	169	72	73	464
1989	0	2	0	220	220	144	562	439	181	147	18	0	562
1990	0	37	28	100	161	318	475	177	43	202	64	36	475
1991	19	0	40	103	254	381	416	311	226	88	139	13	416
1992	0	79	0	1	78	445	148	168	177	321	3	34	445
1993	9	71	144	91	236	526	246	428	87	66	14	0	526
1994	7	7	174	156	80	353	153	167	55	67	11	0	353
1995	0	8	18	34	263	144	280	387	84	33	127	0	387
1996	0	85	91	168	109	310	240	251	109	189	186	1	310
1997	0	29	102	20	145	158	412	204	240	159	49	4	412
1998	37	89	87	175	179	68	559	437	315	57	93	0	559
1999	0	0	0	0	179	530	263	549	99	128	7	107	549
2000	12	5	9	57	524	280	438	460	103	286	57	15	524
2001	0	12	1	23	307	404	146	138	125	93	77	0	404
2002	1	1	69	37	188	102	458	140	56	71	113	23	458
2003	0	0	45	97	67	423	382	175	83	162	11	66	423
2004	0	0	3	67	158	364	548	74	447	162	0	0	548
2005	5	0	51	78	73	141	273	261	244	57	20	8	273
2006	0	0	0	40	665	468	228	70	251	64	16	0	665
2007	0	30	4	110	127	632	446	305	410	353	118	0	632
2008	55.7	7.6	14.1	1.1	103	425.8	395.5	318.2	267	117.1	42.6	0	425.8
2009	0	1.8	79.3	233.8	231.5	474.3	472.5	113.4	160.5	38.2	0	0	474.3
2010	8.8	0	38.1	135.3	459.2	144.7	118.8	40.6	198.7	3.6	22.3	1.8	459.2