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HISTORICAL TRENDS AND FUTURE PROJECTION OF CLIMATE AT DHAKA CITY OF BANGLADESH

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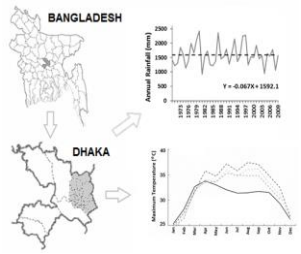
Graphical abstract



Abstract

Dhaka, the capital city of Bangladesh is considered as one of the most vulnerable cities of the world to climate change. A study has been carried out to assess the historical changes as well as future changes in the climate of Dhaka city in order to propose necessary mitigation and adaptation measures. Statistical downscaling model (SDSM) was used for the projection of future changes in daily rainfall and temperature and non-parametric trend analysis was used to assess the changes in rainfall, temperature and related extremes. The impacts of projected changes in climate on urban infrastructure and livelihood in Dhaka city was finally assessed to propose necessary adaptation measures. The study revealed that night time temperature in Dhaka city has increased significantly at a rate of 0.22°C/decade in last fifty year, which is support to increase continually in the future. Different temperature related extreme events are also found to increase significantly in Dhaka. On the other hand, no significant change in rainfall or rainfall related extremes are observed. Therefore, it can be remarked that imminent impacts of climate change will be due to the increase in temperature and temperature related extremes. The public health and the water and energy supply are likely to be imminent affected sector in the city due to climate change.

Keywords: Climate change, future projection, non-parametric analysis, downscaling model, Dhaka city

1.0 INTRODUCTION

The world's population will reach to 9.6 billion in 2050 and the major portion (66%) of the World's population will live in urban area [1]. It has been projected that even in the less developed countries, a majority of people will be living in urban areas by 2017 [2]. This will due to rapid urbanization and huge migration of rural population to urban areas [3, 4]. High population density will make many cities particularly those are located in developing countries highly vulnerable to climate change due to inadequate infrastructure and poor management capacity [5]. It has been projected the urban population in developing countries will be much more vulnerable in near future, if proper adaptation measures are not taken [6, 7].

Dhaka, the capital of Bangladesh, is the largest city of the country where about 14.6 million people live in an area of only 1530.84 km^2. Uneven physical expansion compared to population growth caused an extremely high population density in Dhaka. Insufficient infrastructure for huge population has caused incredible stress on the urban utility services and other facilities of urban life in the city. A large number of people particularly those are settled in slums and squatters have very limited access to urban services like safe water and continuous energy supply, sanitation facilities and waste disposal. Access to health and education is also limited to many of the dwellers [8]. These along with poor institutional capacity, inadequate financial resources and insufficient infrastructure have made the Dhaka as the most vulnerable city of the world [9].

Geographically, Dhaka is located in central Bangladesh in the lower reaches of the Ganges Delta (Figure 1). The climate of Dhaka can be classified as wet humid with an annual average rainfall varies between 2000 mm and 3000 mm [10]. The seasonal

variations in rainfall and temperature at Dhaka city is shown in Figure 2 in period 1971-2101. It is projected that global warming will cause sharp increase in temperature and changes in precipitation pattern in Dhaka city, which will in turn change various weather related extreme events [11, 12]. Therefore, it can be anticipated that climate change will make the people of Dhaka more vulnerable in near future.

Understanding ongoing changes in the climate is essential for adaptation planning [13]. The major objective of this paper is to use various statistical approaches to understand the ongoing and possible future changes in the climate of Dhaka city in order to assess the possible impacts of climate change on urban infrastructure and livelihoods. The adaptation measures that can be adopted to build resilience are also discussed. It is expected that the finding of the study will help policy makers and urban planners to adopt necessary adaptation and mitigation measures.

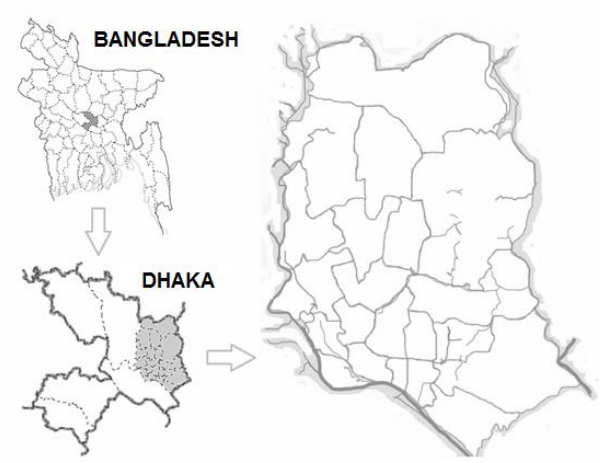


Figure 1 Location of Dhaka city in the map of Bangladesh

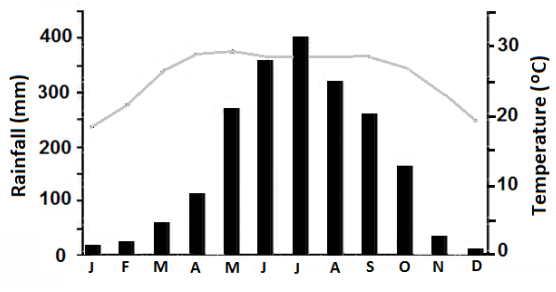


Figure 2 Seasonal variation of rainfall and temperature at Dhaka city (1971-2010)

2.0 MATERIALS AND METHODS

2.1 Data and Sources

Climate change impacts on Dhaka city were analyzed based on ongoing changes and future projections of the climate and climate-related extreme events in the city. Long-term daily rainfall and temperature records (1961-2010) from a meteorological station located in Dhaka were collected from Bangladesh Meteorological Department and used in the study. Data quality control is a necessary step before the calculation of indices because erroneous outliers can seriously impact the indices calculation and their trends [15]. Therefore, a number of quality control checks were carried out to identify errors such as precipitation values below 0 mm, winter rainfall higher than 100 mm, more than ten consecutive dry days in monsoon, minimum temperature higher than maximum temperature and temperature values less than 2°C. Histogram of daily rainfall at Dhaka station revealed no problem in the data set. A subjective double-mass curve method and an objective Student t-test were used to assess in homogeneities in the data series. Both the methods insured homogeneity in data.
For the downscaling of future climate projection at Dhaka city, the predictors were obtained from the National Centre for Environmental Prediction (NCEP) reanalysis data set. Twenty-six NCEP variables that are usually projected by various climate models including Hadley Centre Climate Model (HadCM) were used in the present study for the selection of predictors. Future projections of climate by global circulation model (GCM) known as HadCM3 was used for the downscaling of projected rainfall and temperature at Dhaka city.

2.2 Trend Analysis of Climate and Climate Related Extremes

The non-parametric Mann–Kendall trend test [15] was used to analyze the trends in climate and climate-related extreme events. The Sen's slope method [16] was used to estimate the magnitude of change.
In Mann-Kendall (MK) test the data values are evaluated as an ordered time series. If X_1, X_2, X_3 ..... x_i represent n data points where x_j represents the data point at time j, then S is given by,

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sign(x_j - x_k)$$

Where: $$sing(x_j - x_k) = \begin{cases} 1 & if\ x_j - x_j > 0 \\ 0 & if\ x_j - x_j = 0 \\ -1 & if\ x_j - x_j < 0 \end{cases}$$

Normalized test statistic Z is computed as follows:

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

The null hypothesis of no trend is rejected at p=0.01, if $|Z| > 2.575$; and at p=0.05, if $|Z| > 1.96$.

Sen's method proceeds by calculating the slope as a change in measurement per change in time,

$$Q' = {x_t' - x_t}/{t' - t} \quad (4)$$

Where, $Q^{/}$ is slope between data points $x_{t^{/}}$ and x_t; $x_{t^{/}}$ is data measurement at time $t^{/}$, and x_t is the data measurement at time t. Sen's estimator of slope is simply given by the median slope,

$$Q = \begin{cases} Q^{/}_{[\frac{n+1}{2}]} & if\ N\ is\ odd \\ \left(Q^{/}_{[\frac{N}{2}]} + Q^{/}_{[\frac{n+1}{2}]}\right)/2 & if\ N\ is\ even \end{cases}$$

Where, N is the number of calculated slopes.

Confidence levels of 90%, 95% and 99% were set as thresholds for determining significant temperature trends. A number rainfall and temperature-related extreme indices were estimated some of which were based on thresholds defined as percentiles. The percentiles were calculated from the reference period 1961-1990, which is considered the "current climate normal period" by the World Meteorological Organization [14]. The indices include (i) days with rainfall more than 20 mm; (ii) days having rainfall more than 95 percentile of the rainfall in reference period; (iii) continuously dry days in a year; (iv) continuously wet days in a year; (v) days having maximum temperature more than 32°C; (vi) days having minimum temperature more than 25°C.

2.3 Statistical Downscaling Model

Statistical Downscaling Model (SDSM) was used to project future change in rainfall and temperature at Dhaka city. SDMS is a widely used downscaling tool developed by Wilby and Wigley [17]. SDSM uses multiple linear regression technique for the development of downscaling model [18]. It develops the model by establishing the statistical relationship between the predict and predictors in the first step and then simulate the future series of predict and by using the predicted data from GCMs. SDSM uses two separate sub-models to determine the occurrence and the amount of conditional meteorological variables (or discrete variables) such as precipitation [19]. Therefore, SDSM can be classified as a conditional weather generator in which regression equations are used to estimate the parameters of daily precipitation occurrence and amount, separately. Therefore, it is more sophisticated than a straightforward regression model [20]. In this study, climate projections by HadCM3 model under B2 scenario were used to projection climate change in future at Dhaka city.

3.0 RESULTS AND DISCUSSION

3.1 Characteristics of Climate at Dhaka

The annual average rainfall and temperature of Dhaka city along with other statistics are given in Table 1. The mean rainfall of Dhaka city (2073.9 mm) is a bit less than the average rainfall (2400 mm) of the whole country. However, year to year variation in rainfall is only 19.7%. It indicates that rainfall at the city is more or less reliable. Daily mean minimum and maximum temperatures at Dhaka are very near to average of the whole country. However, diurnal temperature range is found less compared to other cities. This may be due to urban heat island effect.

Table 1 Statistical summary of rainfall and temperature in Dhaka city over the time period 1971-2010

Parameters	Dhaka
Mean Rainfall	2077.2
Standard Deviation of Rainfall	409.6
Coefficient Of Variance of Rainfall	19.9
Daily Mean Temp	26.6
Daily Mean Max Temp	30.8
Standard Deviation of Daily Max Temp	3.4
Daily Mean Min Temp	21.7
Standard Deviation of Daily Min Temp	5.2
Diurnal Temperature Range	8.8

3.2 Trends in Temperature and Rainfall

Trends in annual and seasonal temperatures at Dhaka are given in Table 2. The numbers in the table show changes of temperature in °C/year. Bold numbers in the table denote change at the 95% level of confidence and italicized-bold numbers denote change at the 99% level of confidence. Average annual maximum and minimum temperature of Dhaka station is shown in Figure 3.

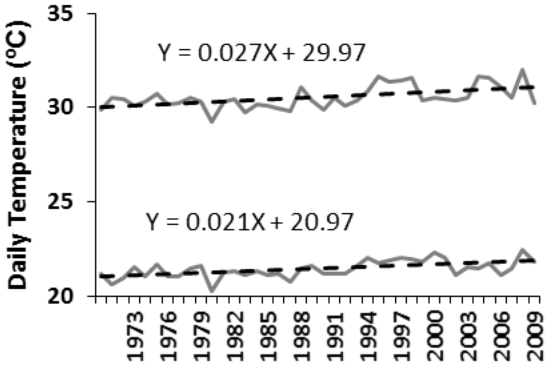


Figure 3 Average annual maximum and minimum temperature at Dhaka during 1971-2010

Figure 3 shows that although average annual maximum and minimum temperature had fluctuation during period in Dhaka station, both maximum and minimum temperature increased during period. Trend in average annual maximum and minimum temperature were positive and approximately were 2.7 and 2.1 0C/century, respectively. Changes in average annual maximum temperature was

significant at 99% confidence level, but for average minimum temperature was not significant. Shahid [17] showed that global climate change had effect on temperature and caused rising in it. Moreover, Table 2 shows significant increase in daily average minimum temperature, but no change in daily average maximum temperature in Dhaka. Minimum temperature increased more than maximum temperature in Dhaka. Seasonal analysis of temperature trends shows a significant increase of minimum temperature at Dhaka in all seasons. Maximum temperatures in monsoon and post-monsoon seasons also increased significantly in Dhaka during the study period. Analysis of the changes of annual diurnal temperature range (DTR) shows (Table 2) decrease of DTR in Dhaka. The decrease of DTR at Dhaka is due to the increase of minimum temperature, but no significant change in maximum temperature [18]. It indicates that urban heat island effect due to urbanization has caused an increase in night temperature and decrease in DTR of Dhaka city. Seasonal analysis of DTR shows significant increase of monsoon DTR and decrease of winter DTR in Dhaka. Average annual rainfall in Dhaka station is shown in Figure 4. Figure shows that average rainfall decrease during period time. The trend average rainfall was negative, -0.066 mm/year. Although the trend of average annual rainfall is negative, decrease of rainfall is not significant. Seasonal analysis of rainfall trends at Dhaka city also showed no significant change in seasonal rainfall at Dhaka city. Therefore, it can be remarked that annual and seasonal rainfall at Dhaka city has not changed significantly in last forty years.

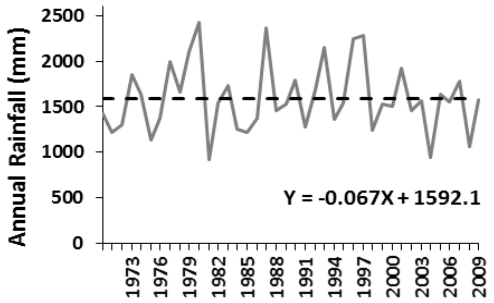


Figure 4 Average annual rainfall a Dhaka station during 1971-2010

3.3 Trends in Temperature and Rainfall Related Extremes

Results of a trend analysis of temperature and rainfall related extreme events in Dhaka are presented in Table 3. Numbers in the table represent changes per decade. Results show that the number of hot days (Maximum Temperature > 32°C) and hot nights (Minimum Temperature > 25°C) have increased in Dhaka. It indicates that an increase in daily minimum and maximum temperatures have changed temperature-related extreme events in Dhaka. Trends in rainfall related extreme events show no changes in any of the extreme rainfall indices in Dhaka city.

Table 2 Annual and seasonal trends in temperature and rainfall at Dhaka city over the time period 1958-2012

Parameter	Season		Change (per year)
Temperature (in °C)	Winter	Min	***0.055***
		Max	0.002
	Pre-monsoon	Min	***0.022***
		Max	0.009
	Monsoon	Min	***0.009***
		Max	***0.032***
	Post Monsoon	Min	***0.032***
		Max	***0.035***
	Annual	Min	***0.022***
		Max	0.007
Diurnal Temperature Range (in °C)	Winter		***-0.058***
	Pre-monsoon		-0.017
	Monsoon		***0.024***
	Post-Monsoon		0.003
	Annual		**-0.009**
Rainfall (mm)	Winter		0.18
	Pre-Monsoon		-0.32
	Monsoon		-0.93
	Post-Monsoon		0.43
	Annual		-0.81

Bold numbers denote change at 95% level of confidence; Bold and Italic numbers denotes change at 99% level of confidence.

Table 3 Trends in temperature and rainfall related extremes at Dhaka city over the time period 1958-2012

Index	Change
Max Temp > 32°C	***1.64***
Max Temp >25°C	***0.63***
Days with 95 percentile rainfall	0.00
Days with rainfall > 20 mm	0.00
Continuous dry days	0.16
Continuously wet days	-0.04

Bold numbers denote change at 95% level of confidence; Bold and Italic numbers denotes change at 99% level of confidence.

3.4 Future Projection of Climate at Dhaka City

Downscaled rainfall and temperature obtained using SDSM under B2 scenarios are shown in Figure 5. Figures 5(a) and (b) show that maximum and minimum temperature at Dhaka city will continue to increase throughout the present century. Maximum increase in maximum temperature will be in the months of August and September.

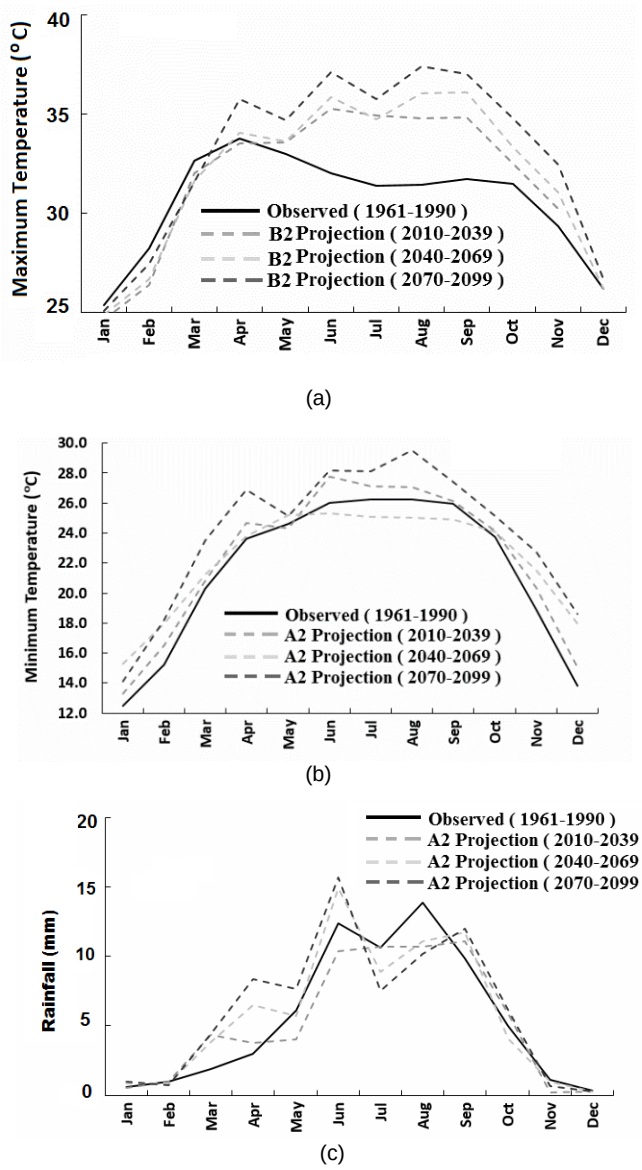


Figure 5 Projection climate change in future a) Maximum monthly temperature b) Minimum monthly temperature and c) Monthly rainfall

On the other hand, maximum temperature during winter will decrease at Dhaka city in the future. Minimum temperature was also projected to increase continuously throughout the present century. The rise of minimum temperature will be in all months of a year. The maximum increase will be April and August. However, increase of minimum temperature will be less than maximum temperature. Any changes in mean and standard deviation change extreme values. Therefore, it can be remarked that increase temperature will be associated with increase in temperature related extremes at Dhaka city.

The results revealed that rainfall at Dhaka city will not change significantly in many months. The projection showed rainfall at Dhaka city will increase mostly during pre-monsoon months and decrease during monsoon. However, rainfall in the month of June, which is the first month of monsoon was projected to increase very high compared to other months. Increase of rainfall in a single month indicates increase of extreme rainfall events. Overall, the climate projections showed that the climate of Dhaka city will follow the historical trends. Temperature will continue to increase, but the change of rainfall will not be very high in near future. Any change in rainfall will be noticeable at Dhaka in the end of this century.

The results obtained in the present study are compared with the finding of other studies. Shahid [12, 21] analyzed the trends in rainfall and temperate of Bangladesh and reported that the annual and season rainfall only in some parts of west Bangladesh has increased significantly. However, increase of rainfall is not significant in other parts including Dhaka. Shahid [12] also reported that the mean temperature of Bangladesh has increased by 0.097°C per decade in last 50 year. The mean maximum and mean minimum temperatures are also increased significantly including Dhaka. The present study shows that temperature in Dhaka city has increased more rapidly compared to country average. Seasonal analysis of temperature over Bangladesh by Shahid [21] showed that the temperature has increasing significantly only in winter. The present studies showed that minimum temperature in Dhaka city has increased almost all season with strong increase in winter. Minimum temperature during winter has increased at a rate of 0.54°C per decade in Dhaka. The finding of present study on DTR also collaborates with the finding of Shahid *et al*. [21].

The minimum temperature of Dhaka city has increased rapidly after early nineties. However, the maximum temperature has not changed significantly over the time period. Rapid increase of daily minimum temperature and no significant change in daily maximum temperature caused significant decrease of diurnal temperature range in Dhaka city after mid-nineties. The result indicates that urban heat island effect due to rapid urbanization has caused an increase in night temperature and decrease in DTR of Dhaka city.

Climate of Dhaka city projected in present study is also similar to the finding of the other studies based on various climate models under different greenhouse gas emission scenarios [22, 23, 24, 25]. OCDE [22] reported an average temperature rise of 1.3°C by 2030 for Bangladesh with more warming for winter (1.1°C) than for summer (0.8°C). The models also projected increased precipitation in annual, pre-monsoon, monsoon and post-monsoon seasons and no appreciable change in winter season. Rajib *et al*. [23] used an ensemble of models to project precipitation changes for Bangladesh under SRES A1B scenario and reported that the precipitation might continue to increase in all the months in future years. Rahman *et al*. [24] reported that temperature variability will appear to be a major aspect as a consequence of extreme climatic changes. Rajib *et al*.

[23] reported that rainfall will be concentrated more during time period 2071-2100 compared to the period 1971-2000, which means that rainfall related extremes such as heavy rainfall events, rainfall intensity, etc. may increase. Rahman *et al*. [25] reported increased temperature in different months by 0.5°C to 2.1°C in the middle of 21st century. From the above discussion, it can be concluded that rainfall, temperature and climate related extreme events will continue to increase in Bangladesh. The present study indicates that climate at Dhaka will follow the similar pattern in future that has been projected by different authors for the whole country.

4.0 POSSIBLE IMPACTS AND ADAPTATION OF CLIMATE CHANGE IN DHAKA CITY

From the above studies, it can be summarized that significant increase of temperature and temperature related extreme events, but almost no change in rainfall and rainfall related extreme events in Dhaka city in last fifty years. Increased temperature in Dhaka city is mostly due to the effect of urban heat island effect. Future projection of climate at Dhaka city by SDSM reveals continuous increase of temperature in Dhaka city.

The vulnerability of climate change on urban population of Bangladesh is measured by considering certainty and timing of impact. Certainly of impact uses available knowledge of climate change to assess the likelihood of impacts and the timing implies whether they are likely to manifest themselves in the first or the second half of this century. The present study shows that the urban areas of Bangladesh are already facing an increased daily temperature and related extreme events. Though an increase of rainfall in Bangladesh has been predicted by most of the climate models, it is still not significantly visible in Bangladesh. Therefore, it can be concluded that imminent impacts of climate change in Bangladesh will be due to the higher daily temperature and temperature related extreme events. The impacts will certainly be very much diverse from public health to urban water system and energy demand. However, public health and urban infrastructures viz. water supply and power supply would be the most imminent affected sectors of climate change in the city [26].

Analysis of climate change impacts on various urban sectors suggest that development of climate resilient infrastructure is essential for Dhaka city, which should include up gradation or retrofication of poor structures, replacement of vulnerable infrastructure, redesigning of urban flood control infrastructure, development of resilient water and sanitation systems, planning energy efficient construction, etc. It is necessary to incorporate climate change issues into every planning, design, construction, operation and maintenance of urban infrastructure. The structural measures to adapt with climate change will certainly cause huge financial burden for Bangladesh. Therefore, the future research should be envisaged to find the cost effective measures.

5.0 CONCLUSION

Historical rainfall and temperature data of Dhaka city was analyzed to assess the recent changes in the climate of Dhaka. SDSM was also used to downscale future projections of climate at Dhaka city. The study revealed that the climate change would cause continuous increase of rainfall, temperature and weather related extreme events in Dhaka. However, the most imminent impacts of climate change in Dhaka will be due to the rise of temperature and related extremes, such as, frequent outbreak of tropical diseases, scarcity of water, increased demand of power, etc. It is necessary to incorporate climate change adaptation guidelines into all planning, design, construction, operation and maintenance of urban infrastructure of Dhaka city. It is expected that the finding of present study will help to enhance the knowledge on ongoing changes in the climate and climate related extreme events, possible future scenarios of climate, impacts of climate change on different sectors of Dhaka city according to their certainty and timing. It will also help to identify the possible adaptation measures to mitigate the negative impacts of climate change in Dhaka, which is the political and financial center of the country. Appropriate strategies based on the climate information presented in this paper will reduce the vulnerability of urban livelihoods and infrastructures to future climate change and contributes to achieve sustainability in resources.

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References

[1] Wang, X.-J., Zhang, J.-Y., Shahid, S., Guan, E.-H., Wu, Y.-X., Gao, J. and He, R.-M. 2014. Adaptation To Climate Change Impacts On Water Demand. *Mitigation And Adaptation Strategies For Global Change*. DOI: 10.1007/s11027-014-9571-6.

[2] United Nations. 2014. World Urbanization Prospects, The 2014 Revision: Highlights. Population Division, Department of Economic and Social Affairs, United Nations (ST/ESA/SER.A/352), 2014.

[3] Wang, X.-J., Zhang, J.-Y., Shahid, S. *et al*. 2013. Historic Water Consumptions And Future Management Strategies For Haihe River Basin Of Northern China. *Mitigation And Adaptation Strategies For Global Change*. DOI: 10.1007/s11027-013-9496-5.

[4] Wang, X.-J., Zhang, J.-Y., Liu, J.-F., He, R.-M., Amgad, E., Wang, X.-G., King, D. and Shahid, S. 2012. Climate Change And Water Resources Management In Tuwei River Basin Of

Northwest China. *Mitigation and Adaptation Strategies for Global Change*. 19: 107-120.
[5] Shahid, S., Wang, X. J., Harun, S. B., Shamsudin, S. B., Ismail, T., and Minhans, A. 2015. Climate Variability And Changes In The Major Cities Of Bangladesh: Observations, Possible Impacts And Adaptation. *Reg. Environ. Change*. 1-13.
[6] Shahid, S. 2011. Trends in Extreme Rainfall Events of Bangladesh, *Theoretical and Applied Climatology*. 104(3-4): 489-499.
[7] Shahid, S. 2010. Probable Impacts Of Climate Change On Public Health In Bangladesh. *Asia-Pacific Journal of Public Health*. 22(3): 310-319.
[8] Eusuf, A. Z. 1996. Urban Centres In Bangladesh: Their Growth And Change In Rank-Order. In: Islam, N. and Ahsan, R. M. (eds). Urban Bangladesh. Urban Studies Program, Dhaka. 7–20.
[9] Islam, N. 1994. Urban Research In Bangladesh And Sri Lanka: Towards An Agenda For The 1990s. In: Stren R (Ed). Urban Research In Developing World, Toronto: Centre For Urban And Community Studies, University of Toronto. 101-169.
[10] Shahid, S. and Khairulmaini, O. S. 2009. Spatio-Temporal variability of Rainfall over Bangladesh during the time period 1969-2003. *Asia-Pacific Journal of Atmospheric Sciences*. 45(3): 375-389.
[11] Shahid, S. 2010. Rainfall Variability And The Trends Of Wet And Dry Periods In Bangladesh. *International Journal of Climatology*. 30(15): 2299-2313.
[12] Shahid, S. 2010. Recent Trends In The Climate Of Bangladesh. *Climate Research*. 42(3): 185-193.
[13] Batisani, N, and Yarnal, B. 2010. Rainfall Variability And Trends In Semiarid Botswana: Implications For Climate Change Adaptation Policy. *Appl. Geogr*. 30(4): 483-489.
[14] Alamgir, M., Shahid, S., Hazarika, M.K., Nashrrullah, S., bin Harun, S. and Shamsudin, S. 2015. Analysis Of Meteorological Drought Pattern During Different Climatic And Cropping Seasons In Bangladesh. *JAWRA Journal of the American Water Resources Association*. DOI: 10.1111/jawr.12276.
[15] Kendall, M. G. 1975. *Rank Correlation Methods*. Griffin, London.
[16] Sen, P. K. 1968. Estimates of the regression coefficient based on Kendall's tau. *J. Am. Stat. Assoc*. 63: 1379-1389.
[17] Wilby, R. L. and Wigley, T. M. L 2000. Precipitation Predictors For Downscaling: Observed And General Circulation Model Relationships. *Int. J. Climatol*. 20: 641-661.
[18] Ahmed, K., Shahid, S. and Harun, S. B. 2014. Spatial Interpolation Of Climatic Variables In A Predominantly Arid Region With Complex Topography. *Environ. Syst. Decis*. 34(4): 555-563.
[19] Pour, S. H., Harun, S. B. and Shahid, S. 2014. Genetic Programming For The Downscaling Of Extreme Rainfall Events On The East Coast Of Peninsular Malaysia. *Atmos*. 5: 914-936.
[20] Wilby, R. 1998. Statistical Downscaling Of Daily Precipitation Using Daily Airflow And Seasonal Teleconnection Indices. *Clim. Res*. 10: 163-178.
[21] Shahid, S., bin Harun, S. and Katimon, A. 2012. Changes In Diurnal Temperature Range In Bangladesh During The Time Period 1961-2008. *Atmospheric Research*. 118: 260-270.
[22] OECD. 2003. Development And Climate Change In Bangladesh: Focus On Coastal Flooding And The Sundarbans. In: Agrawala, S., Ota, T. and Ahmed A.U. (eds). Organization for economic co-operation and development (OECD) report COM/ENV/EPOC/DCD/DAC(2003)3/FINAL, Paris, France. www.oecd.org/dataoecd/46/55/21055658.pdf. Accessed 24 Oct 2011.
[23] Rajib, M. A., Rahman, M. M., Islam, A. K. M. S. and McBean, E. A. 2011. Analyzing The Future Monthly Precipitation Pattern In Bangladesh From Multi-Model Projections Using Both GCM And RCM. *World Environmental and Water Resources Congress 2011: Bearing Knowledge for Sustainability*. 3843-3851.
[24] Rahman, M. M., Rajib, M. A., Hassan, M. M., Iskander, S. M., Khondoker, M. T. H., Rakib, Z. B. and Ankur, A. K. 2012b. Application of RCM-based Climate Change Indices In Assessing Future Climate: Part II Precipitation Concentration. *World Environmental and Water Resources Congress 2012: Crossing Boundaries*. 1787-1793.
[25] Rahman, M. M., Islam, M. N., Ahmed, A. U. and Georgi, F. 2012a. Rainfall And Temperature Scenarios For Bangladesh For The Middle Of 21st Century Using RegCM. *J. Earth Syst. Sci*. 12(2): 287-295.
[26] Shahid, S. 2012. Vulnerability Of The Power Sector Of Bangladesh To Climate Change And Extreme Weather Events. *Regional Environmental Change*. 12(3): 595-606.