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An Assessment of Climate Change Vulnerability Index at District Level of Bangladesh In Context of Extreme Temperature and Precipitation

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Abstract

Bangladesh is unique with her geographical setting and dense population making the country very vulnerable to climate change. Global warming is only to worsen the situation increasing socio-economic as well as natural hazards enhancing more vulnerable condition. So, carrying out of an assessment of climate vulnerability index was important for Bangladesh in context of extreme temperature and precipitation. Climate Vulnerability Index Method is used for the purpose of assessing the present and future climate change vulnerability as a function of exposure, sensitivity, and adaptive capacity considering natural and socioeconomic indicators at district level of Bangladesh. This study projects the vulnerability index for a base period (2011)for 64 districts of Bangladesh and compares it with three future climate change vulnerability index scenarios for 2030, 2050 and 2080. Historical data from 1971–2000 as daily maximum and minimum temperature and daily average precipitation were used to assess exposure in respect to the base period. Future projections for RCP 8.5 for MPI-MPI-ESM dataset were used to estimate future exposure. This method has been used to convert these various sets of data into a common index which is readily understood. Generated maps might be used by policy makers for effective planning and management of future vulnerabilities.

Keywords:*adaptive capacity, climate indices, , sensitivity, SU35, vulnerability index*

1. Introduction

“It is demonstrated by Nicholls et al. 2008 [1] that climate change impacts result from the interaction between climate and non-climate drivers and have significant regional variations.” That is why, vulnerability analysis should adopt an integrated approach which considers both natural climate variability and socio-economic drivers. The term “vulnerability occurs with different meaning depending on social scientists and climate scientists. “According to Allen, 2003 [2] social scientists tend to view vulnerability as representing the set of socio-economic factors that determine people’s ability to cope with stress or change” On the other hand, “Nicholls et al., 1999 [3] reports that climate scientists often view vulnerability in terms of the likelihood of occurrence and impacts of weather and climate related events. However, regarding vulnerability to climate change, “according to Ramieri et al. 2011 [4] the IPCC define this as a function of the character, magnitude, and rate of climate change to which a system is exposed, its sensitivity, and its adaptive capacity.”

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2. Data and Method

2.1. Data Collection

Extreme temperature and precipitation with their potential future changes were evaluated according to Intergovernmental Panel on Climate Change (IPCC) diagnostic exercise for the Fifth Assessment Report (AR5) which was an assemble of 5th Phase Coupled Model Inter-comparison Project (CMIP5). This CIMP5 regional climate modeling system analyses the distribution of extremes of temperature and precipitation in Bangladesh in the recent past (1971–2000) and in a future scenarios 2030, 2050 and 2080. For this particular vulnerability analysis MPI-MPI-ESM (Max Planck Institute for Meteorology (MPI-M), the new Earth System Model) dataset was used with RCP 8.5 scenario.

The socio-economic indicators were obtained from Statistical Yearbook of Bangladesh 2013, BBS. Total 26 socio-economic indicators are used in the assessment of climate change vulnerability of which in the sensitivity assessment 15 indicators and for the adaptive capacity, 11 indicators are used and shown in Table 1. For exposure, 17 temperature and precipitation indicators are exercised in the assessment with explanations and presented in Table 1.

2.1.1. Socio-economic Indicators

The present population of Bangladesh is 144043697 as per BBS, 2013 [5] and the future projection of population by age group is found by multiplying present population classified as per age groups such as 0-14, 15–24, 25–54, 55–64 and over 64 with their corresponding growth rate using the information described in CIA World Factbook, 2014 [6]. Thus the total future population for the year 2100 was found 182494721. The estimated projected population for the year 2100 was checked comparing the information presented in Population Pyramids of the World [7]. The projections given by the 4th IPCC for potential population to be affected and land loss to be occurred due to 1 m sea level rise show that 17,000 square kilometer land along the coastal areas will go under water. So, socio-economic indicators were estimated taking into consideration of 1 m sea level and its impacts for the projected year 2100.

2.1.2. Climate Indices

The maximum and minimum temperature and daily precipitation data obtained in this study were split into four periods as base period (1971–2000) and future periods 2030s, 2050s and 2080s. The Quality Control (QC) was checked using the RClimDex software package. All unreasonable values for the meteorological variables were considred as missing. Unreasonable values include daily precipitation amounts less than zero and daily maximum temperature less than daily minimum temperature and were replaced with a code (-99.9).

Out of 63 stations in Bangladesh, 59 stations with the most complete data (less than 1% of missing data for a period of 130 years from 1971 to 2100 were chosen and 27 climate indices were found of which 17 indices were considered as suitable enough for this study. "Tank et al. 2009 [8] reports that, These indices were developed by the World Climate Research Program's Expert Team on Climate Change Detection and Indices (ETCCDI)."

Table-1.Summary of all socio-economic and climate indicators

Adaptive Capacity	Sensitivity	Exposure	Explanation of Climate Indices
Population Density	Irrigated Area	Warm spell duration index: WSDI	At least 6 consecutive days in a year when TX > 90th percentile
Literacy Rate	Intensity of Cropping	Cold spell duration index: CSDI	At least 6 consecutive days in a year when TX< 10th percentile
Child-Women Ratio	Area of Pond	Number of frost days: FD5	Annual count of days when TN (daily minimum temperature) < 5°C
Economic Activeness	Hybrid Boro Area	Number of icing days: ID20	Annual count of days when TX (daily maximum temperature) < 20°C
Population Engaged in	Wheat Area	Number of summer days:	Annual count of days when TX (daily

Agriculture		SU25	maximum temperature) > 25°C
No. of Non-Farm Holding	Jute Area	Number of summer days: SU35	Annual count of days when TX (daily maximum temperature) > 35°C
No. of Small Farm Holding	Sugar-Cane Area	Number of tropical nights: TR20	Annual count of days when TN (daily minimum temperature) > 20°C
Agricultural Labor House Hold No.	Oil Seed Area	Number of tropical nights: TR25	Annual count of days when TN (daily minimum temperature) > 25°C
Agricultural Labor House Hold/Area	Potato Area	Annual total precipitation: PRCPTOT	Sum of annual total precipitation in wet days.
No. of Handloom Unit	Ratio of Population and Local Market Facility	R10mm	Annual count of days when PRCP≥ 10mm
Population: Livestock	Electricity Connection	R20mm	Annual count of days when PRCP≥ 20mm
	Power Operating Machinery Use per sq.km	R95p	Annual total PRCP when RR > 95percentile precipitation on wet days
	Ratio of Population and Power Source (Gas)	R99p	Annual total PRCP when RR > 99percentile precipitation on wet days
	Inst. Loan Holdings	R100mm	Annual count of days when PRCP≥ 100mm
	Housing Structure (Pucka)	Simple precipitation intensity index: SDII	SDII is the ratio of sum of RR and wet days when (RR ≥ 1mm)
		Maximum length of dry spell, CDD	Maximum number of consecutive days with RR < 1mm
		Maximum length of wet spell: CWD	Maximum number of consecutive days with RR ≥ 1mm

2.2. Calculating Indicator Score: Index Based Method

Each of the sub-components is measured in different unit. The equation used to convert these indicators was adapted from that used in the Human Development Index to calculate the life expectancy index, UNDP, 2007 [9]. This formula is particularly used when the sub-components have a proportional functional relationship with vulnerability.

$$Index_{X_d} = \frac{X_d - X_{min}}{X_{max} - X_{min}} \quad \ldots\ldots(1)$$

Where, X_d is the original sub-component for district d, X_{min} and X_{max} are the minimum and maximum values, respectively, for each sub-component. "It is demonstrated by Hahn, [10] that, After standardization of each sub-component, all of them are averaged using following equation and value of each major component was calculated."

$$M_d = \frac{\sum_{i=1}^{n} Index_{X_d}}{n} \quad \ldots\ldots(2)$$

Where, M_d = Major component score for district d, $Index_{X_d}$ = index value for each sub-component, n = number of sub-component in each major component. Once, all the values of major components are calculated, the contributing factors of IPCC, which are adaptive capacity, exposure and sensitivity are estimated using equal weight method.

$$CF_d = \frac{\sum_{i=1}^{n} W_i * M_{d_i}}{\sum_{i=1}^{n} W_i} \quad \ldots\ldots(3)$$

CF_d = IPCC-defined contributing factors, W_i = Weight of each major component ('1' in this case). CVI–IPCC is the Climate Vulnerability Index which is calculated for each of the 64 districts in Bangladesh using the IPCC framework.

Vulnerability Index = (Exposure - Adaptive capacity) * Sensitivity…………….(4)

4. Results and Discussions

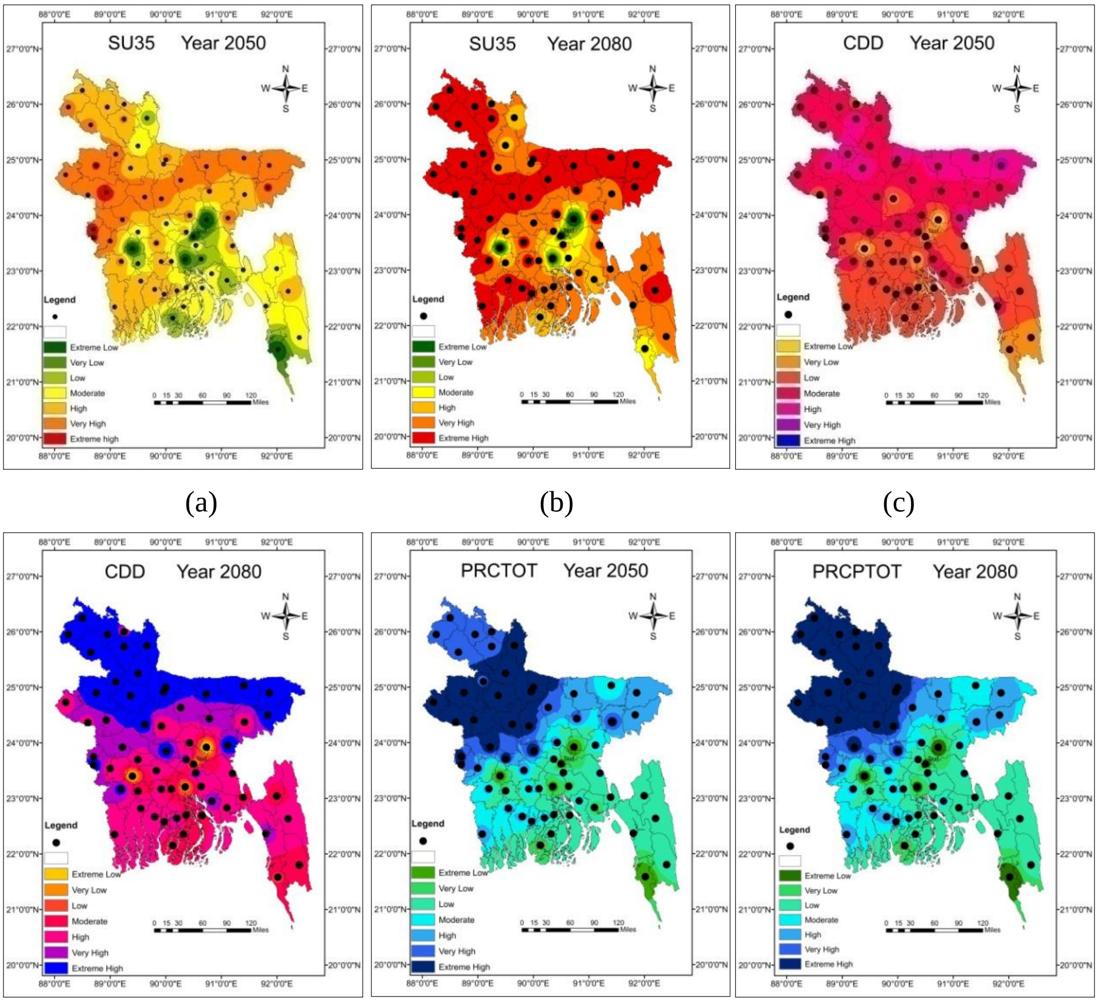
In this paper various aspects of future projections of temperature and precipitation extremes as well as socio-economic changes over Bangladesh are evaluated following RCP 8.5 scenario for MPI-MPI-ESM towards the end of the 21st century. It was found that the major part of Bangladesh would undergo increased extreme precipitation and temperature in future.

4.1 Temperature Indices

Figure 1(a) and 1(b) show the changes in SU35 in terms of the daily maximum temperature for 2050s and 2080s respectively and indicate a general increase of day temperature above 35˚C all over Bangladesh. But northeast and northwest regions of Bangladesh experience strong summer day activeness from March to May. The rest temperature indices - SU25, TR20, TR25, FD5, ID20 are not shown in Fig. 1 but bear the same pattern of temperature increase towards the end of 21st century.

4.2 Precipitation Indices

An increase in CDD is estimated mainly in the northwest region during summer season indicating a substantial decrease of wet days that means decrease in precipitation in summer days towards the dry climate at the end of 2080s.



(a) (b) (c)

(d) (e) (f)

Fig. 1. Spatial patterns of changes (a) & (b) for SU35; (c) & (d) for CDD and (e) & (f) for PRCPTOT for 2050 and 2080 respectively

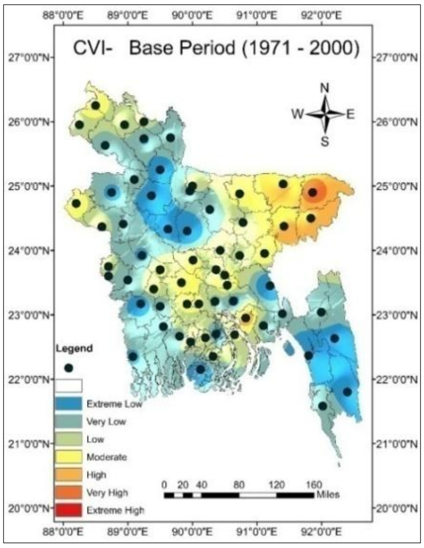
No visible change was found in PRCPTOT for 2050 and 2080 all over the country except northwest region of Bangladesh, where the largest increase in total wet day precipitation was determined. R100 mm, R10 mm, R20 mm, R95p & R99p were also seen in the study with similar projections, but results are not presented graphically.

5. Vulnerability Index

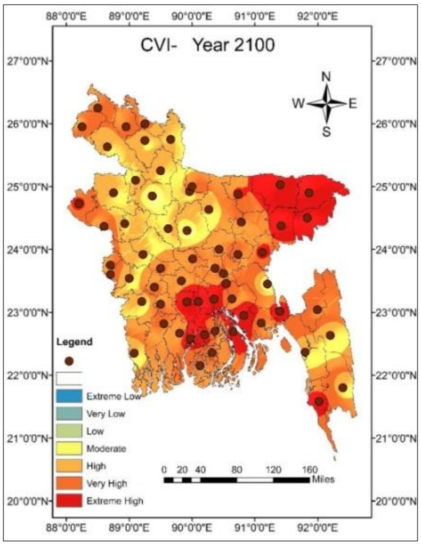
Climate Vulnerability Index (CVI) was estimated for all 64 districts of Bangladesh in terms of adaptive capacity, sensitivity and exposure for the base period (1970-2000) and future year 2100 and shown in Fig. 2(a) & 2(b) respectively. Afterwards, most vulnerable districts were selected through ranking and presented in Table 2 for both the period.

Table-2. Five most vulnerable districts in Bangladesh as per computed CVI

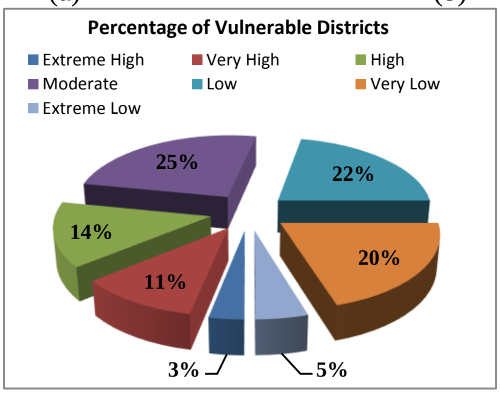
Present Rank	District Name	CVI (Year 2011)	Future Rank	District Name	CVI (Year 2100)
1	Sylhet	0.053	1	Laksmipur	0.146
2	Laksmipur	0.046	2	Sunamganj	0.124
3	Habiganj	0.032	3	Sylhet	0.113
4	Maulavibazar	0.031	4	Jhalokati	0.109
5	Sunamganj	0.030	5	Gopalganj	0.106



(a)



(b)



(c)

Fig. 2. Spatial patterns of changes in Climate Vulnerability Index (CVI) all over Bangladesh in (a) for Base period (1971-2000), (b) for Future Year 2100, (c) Pie Chart showing percentage of vulnerable districts

The CVI assessment shows a substantial increase of vulnerability for all districts of Bangladesh in future year of 2100. Percentage of vulnerable districts is shown in Fig. 2(c) where 3 percentage of districts fall in extreme high vulnerability level, followed by 11 percentage as very high vulnerable level, while 14 percentage of districts as highly vulnerable.

6. Conclusion

As per future projections of temperature and precipitation extremes as well as socio-economic changes over Bangladesh, it may be concluded that the major part of Bangladesh would undergo vulnerable condition induced by extreme temperature change at the end of this century, while impact of precipitation change would be not so dominat in terms of vulnerability. The climate vulnerability assessment through CVI shows a substantial increase of vulnerability of all districts of Bangladesh for future year of 2100. The ranking of vulnerable districts shows that 28 percentage of districts fall in high vulnerable zone, while 25 percentage of districts can be considered as moderate vulnerable and the rest comes under low vulnerable districts. This study may be useful for policymakers as a guidance to improve their understanding on vulnerability risk that Bangladesh would face in future regarding climate and non-climate drivers.

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7. Reference

[1] Nicholls, R.J., Wong, P.P., Burkett, V., Woodroffe, C.D. and Hay, J., *Climate change and coastalvulnerability assessment: scenarios for integrated assessment*, Sustainable Science (3), pp. 89-102, 2008.

[2] Allen, K., *Vulnerability reduction and the community-based approach*, in Pelling (ed.), Natural Disasters and Development in a Globalising World, pp. 170-184. 2003

[3] Nicholls, R. J., Hoozemans, F. M. J. and Marchand, M., *Increasing flood risk and wetland losses due to global sea-level rise: regional and global analyses*, Global Environmental Change, 9, pp. S69-S87, 1999.

[4] Ramieri, E., Hartley A., Barbanti, A., Santos, F.D., Gomes, A., Hilden, M., Laihonen, P., Marinova, N., Santini, M., *Methods for Assessing Coastal Vulnerability to Climate Change*, ETC CCA Technical Paper 1/2011, European Environment Agency, European Topic Centre on Climate Change Impacts, Vulnerability and Adaptation, pp. 13, 2011.

[5] Statistical Yearbook of Bangladesh, Bangladesh Bureau of Statistics, Statistics and Informatics Division, Ministry of Planning, 2013.

[6] CIA World Factbook, Central Intelligence Agency, (accessed 25 March, 2015).

[7] Population Pyramids of the World from 1950 to 2100 Link to this graph: http://populationpyramid.net/bangladesh/2100/ (accessed 25 March, 2015).

[8] Tank. AMGK., Zwiers, FW., Zhang, X., *Guidelines on Analysis ofextremes in a changing climate in support of informed decisions for adaptation*. WMO-TD No. 1500, pp. 1–56, 2009.

[9] UNDP, 2007. Human development reports. http://hdr.undp.org/en/ (accessed 07 May, 2015).

[10] Hahn, M.B., Riederer, A.M., Foster, S.O., *The Livelihood Vulnerability Index: A pragmatic approach to assessing risksfrom climate variability and change—A case study in Mozambique*, Global Environmental Change 19, pp. 74–88, 2009.