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Climate Change Impact: Adaptation Model Evaluates Risk Factors to Reduce Vulnerability

An Adaptation Model has been used to compute adaptation deficiencies that need to be addressed to minimise mid-century climate risks in the coastal zone of Bangladesh. A nonlinear programming system has been formulated in this Model, as such risks are a combination of exposure, hazard and vulnerability factors. This model can help decision makers to take the necessary developmental actions to meet adaptation and environmental policy targets, which will help millions of vulnerable people living under the threat of climate change.

Background

Global warming and anthropogenic climate change, and the need to tackle them are now widely acknowledged as among the greatest challenges facing our society. Adaptation, therefore, has become the focus of climate change research, with policy implications.

Nations with limited adaptive capacity, due to low incomes and the poor access of citizens to infrastructure, services and education, are often the most vulnerable to climate change (UNFCC, 2007; Weiss, 2009). Therefore, the identification of the most effective adaptation options is of utmost importance for a country with severe resource constraints, to maximise benefits from the available resources. Before that happens, however, the zones that are the most vulnerable to climate change need to be identified and adaptation options prioritised in those zones to minimize risks. Figure 1 shows a critical embankment protected by a banyan tree near Galachipa Upazilla, which is a risk hotspot that the adaptation model can identify and address. By analysing the reasons of failure and reconstructing the embankment with the concept of building back better (BBB), the safety of the embankment can be ensured.

Moreover, a particular set of adaptation actions in a specific region may transfer the risk to the adjacent regions. Therefore, the Model has a system approach, and is embedded within the natural and human systems, based on the premise that everything is inter-related and interdependent. This approach considers demography, geographic conditions and the natural variability of climatic events to manage and organise complexity in a region. To accommodate the system response in this study, nonlinear programming was applied to the Adaptation Model. In this model, risk is defined as a nonlinear function of hazard, exposure and vulnerability, following the IPCC AR5 approach (IPCC, 2013).

The model was applied in the coastal zone of Bangladesh, which faces a risk of storm surges, to compute the adaptation deficiency[1] in the risk hotspots, which will help to identify the adaptation required to minimise climate risks.

Key Messages

- The Adaptation Model aims to reduce the risks generated by hazards (such as storm surges, salinity, erosion and floods), and the exposure and vulnerability of a specific region.
- The model will enable government agencies to understand the need for prioritising climate adaptation.
- It will help policy makers to take decisions on investment priorities for risk-based planning to minimise climate risks in a particular area.

Photo Credit: MD. Rayhanur Rahman

Figure 1: A critical embankment protected by a banyan tree near Galachipa Upazilla, Patuakhali.

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1. Adaptation deficiency represents the deficit of an adaptation in a region, is calculated by adaptation deficiency = adaptation need – present value of an adaptation

Model development

The major technical tool of this study is a nonlinear programming system. It is an optimisation tool that involves calculation of the extrema (maxima, minima or stationary points) of an objective function over a set of unknown real variables (known as socio-economic parameters and hazard parameter of this study), and is conditional to the satisfaction of a system of equalities and inequalities, collectively termed as constraints. In this research, an objective function and the related constraints are developed from the weighted scores of domain parameters for the concerned study region. The relative weighted scores are calculated by using Principal Components Analysis (PCA) (Jeong et al., 2009), which is a well-established tool for weight calculation.

How was the model applied to determine adaptation needs?

The Adaptation Model can be applied for risk minimization in any region for any hazard. As an application, the hazard of storm surges was considered to assess the risk in the location where the model was applied. According to Akter, et.al. (2019), 15 indicators were selected from a combined list of the 19 most sensitive and most significant socio-economic indicators to assess the risk from storm surges in the study area.

The indicators are categorised under ‘Exposure’, ‘Sensitivity’ and ‘Adaptive capacity’. Exposure refers to the parameters that are directly affected by any hazard. The Sensitivity domain comes from a combination of demographic and geographic conditions. The greater the exposure or sensitivity, the greater the risk posed to a system. The adaptive capacity indicators represents the level of adaptation in the study area. The indicators in this domain have a negative impact on risk: as adaptive capacity increases, the risks will reduce.

The 15 indicators in table 1 were used to assess the risk of storm surges; the data sources of these indicators are from the year 2011. Figure 2 shows a hotspot map where the model was applied to minimise the risk due to storm surges and the hotspot map has been prepared to show only future risks. Hotspot locations were identified where future risks were high to very high. The top 20 risk hotspots are identified in the study. The year 2050 is considered to be representing the future risk scenario. As the data for socio-economic indicators (indicators of Exposure, Sensitivity and Adaptive Capacity domains) is not available for projections up to 2050, to assess the future risks (which is required to identify the hotspots), only a projection of the risk of storm surges till 2050 has been done by considering the changed external forcing (fluvial flows and sea level) of storm surge events.

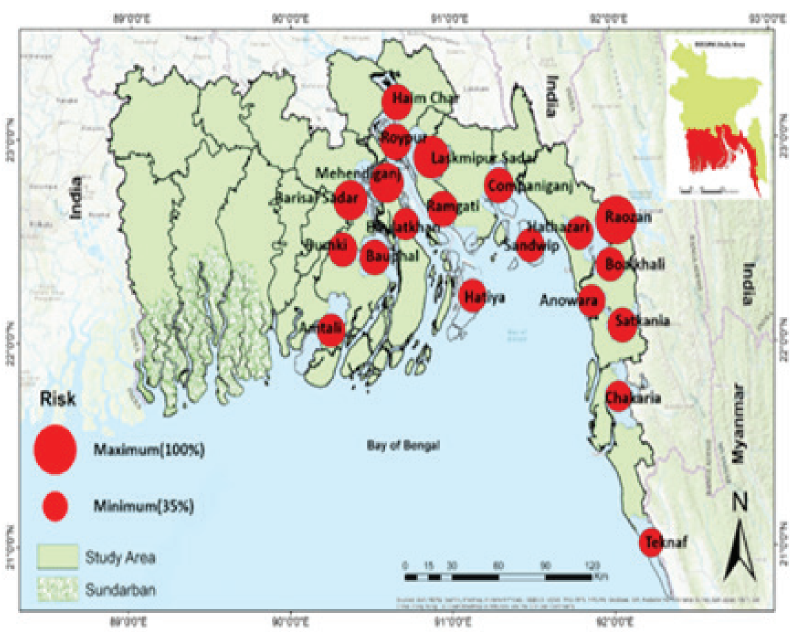

Figure 2: Hotspot due to storm surge

Hence, in these 20 risk hotspots, the Adaptation Model has been applied to compute the adaptation deficiencies, which, if addressed, will minimise the future risks in these hotspots.

Table 1: List of indicators for risks generating from storm surge

Exposure	Adaptive capacity
• Cropped land	• Plantation
• Number of households	• Pucca (permanent) & Semi-Pucca (semi-permanent) House
• Population density	• Loan
Sensitivity	• Polder
• Disabled people	• Growth center
• Dependent people	• Cyclone shelter
• Female to male ratio	• Communication infrastructure
• Poverty rate	• Literacy rate

How can the model be used for investment planning?

The 20 hotspots have been arranged in Table 2 in descending order of ranking. The top ranked hotspot (Raozan) is the location with the maximum future risk score (100), and the bottom ranked hotspot (Teknaf) has lowest future risk score (35), on a normalised 0-100 scale. The adaptation needs in Table 2 are arranged alphabetically, with the higher percentage indicating a higher need for that particular adaptation measure.

This table can be used to decide investment planning on adaptation to minimise future storm surge risks in the study area. The highest percentage in a hotspot shows the maximum adaptation deficiency for the hotspot, which needs immediate investment to minimise future risks there. The maximum adaptation deficiencies in different hotspots are marked as shaded zones in Table 2. For example, Raozan is shown to have the maximum adaptation deficiency1 of 69% in terms of cyclone shelters. It can be seen that the adaptation investment that is needed the most is cyclone shelters in 10 hotspots, followed by plantation (eight hotspots). Two hotspots are equally deficient in two adaptations (cyclone shelters and plantations in Mehendiganj, ranked fourth, and cyclone shelters and polders in Boalkhali, ranked 12th). So, in terms of a single investment priority to minimise future risks in the region, cyclone shelters should get the highest priority, followed by plantations.

Table 2: Computed adaptation deficiency in different hotspots

Hotspot Name	Hotspot Rank	Adaptation Deficiency in Percentage							
		Communication infrastructure	Cyclone shelter	Growth Centre	Literacy Rate	Loan	Pucca & Semi-pucca house	Plantation	Polder
Raozan	1	46	69	36	0	54	50	33	66
Lakshmipur Sadar	2	53	70	53	0	29	48	64	41
Barisal Sadar	3	32	69	56	0	43	45	65	0
Mehendiganj	4	51	62	23	4	44	49	62	18
Roypur	5	31	65	54	0	37	49	55	67
Haim Char	6	42	67	46	7	49	49	17	65
Ramgati	7	30	65	39	20	62	46	73	15
Companiganj	8	50	56	52	0	48	56	70	0
Bauphal	9	49	63	53	0	45	54	67	0
Satkania	10	37	67	37	0	55	51	16	65
Dumki	11	55	66	46	0	36	53	65	8
Boalkhali	12	22	68	46	0	47	49	10	68
Sandwip	13	19	17	41	0	66	70	82	37
Amtali	14	71	60	52	0	24	61	75	0
Hatiya	15	52	40	62	37	38	58	32	31
Hathazari	16	50	85	59	0	53	60	39	84
Anowara	17	27	46	44	0	59	55	74	7
Daulatkhan	18	36	49	56	22	54	56	61	7
Chakaria	19	32	51	46	8	45	57	16	49
Teknaf	20	40	55	59	53	25	56	0	46

Three options for risk-based planning

To reduce future risks in a hotspot to a minimum, policy makers have three options for risk-based investment planning. Option-1: parallel investment in all the adaptations to the required level, as shown in Table 2. This will need substantial investment and may not be a preferred option. Option-2: sequential investment on a particular adaptation in different hotspots, starting with the top ranked hotspot (for example, cyclone shelters, starting with Raozan for this study area). Option-3: sequential investment on different adaptations based on the magnitude of adaptation deficiency, starting with the top-ranked hotspot. For example, in Raozan, investment should be made sequentially in cyclone shelters, polders, loans, pucca (permanent) & semi-pucca (semi-permanent) houses, communication infrastructure, growth centres and plantations. In this hotspot, there is no need for investment in the literacy rate, as the adaptation deficiency is zero here. The selection of any specific option will depend on the availability of funds and priority, based on the socio-political scenario. In all the three options, mentioned above, the investment in any adaptation to meet the required level of deficiency to minimise future risks will increase the present state of adaptation (adaptation deficiency is computed based on the present state or base condition). This will have an impact on the entire socio-economic condition of the study area. The system's response due to this changed socio-economic condition can be computed (results not shown in this application) by iterating the entire application process of the Adaptation Model, i.e., starting from the identification of risk hotspots, formulating a nonlinear programming system, calculating the changed adaptation deficiency and preparing Table 2 for the new condition. With the iterated application of the Adaptation Model, it is possible to invest to reduce the risk of storm surges in the future in all hotspots of the study area to the minimum possible level. Further investment in any adaptation beyond this minimum level will be considered as 'surplus' for the system.

Conclusion

Currently, several organisations are working with the Bangladesh government to reduce climate risks in the coastal area. However, the government and policy makers need to decide on investment priorities after doing risk-based planning. This is particularly important where there are resource constraints and the decisions depend on the socio-political reality of the region. It is also extremely important for them to know how a system will behave (the system here has biophysical and socio-economic components) in case an investment is made in any adaptation at any location. To answer these questions, our model can compute the adaptation deficiencies at a location, which can then be addressed to minimise future climate risks.

In this particular study, the Adaptation Model has been applied in the coastal zone of Bangladesh to compute the adaptation deficiency in 20 hotspots that face a risk of storm surges. The output from the model can be used by policy makers to decide on appropriate investment options for risk-based planning, which will minimise the risk of storm surges in the identified hotspots in the future.

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About IWFM

The Institute of Water and Flood Management (IWFM) is a research institute at Bangladesh University of Engineering and Technology (BUET), established in 1974 as the Institute of Flood Control and Drainage Research, later renamed as IWFM in 2002. The Institute pursues research and capacity development in the field of water and flood management that is vital for economic development and social prosperity of the country.

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