Index Based Climate Vulnerability Assessment for Hatiya of Noakhali of Bangladesh

By

Md. Nahid Hasan Raju

MASTER OF SCIENCE IN WATER RESOURCES DEVELOPMENT

INSTITUTE OF WATER AND FLOOD MANAGEMENT

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY

November, 2015

Index Based Climate Vulnerability Assessment for Hatiya of Noakhali of Bangladesh

By

Md. Nahid Hasan Raju

A thesis submitted to the Institute of Water and Flood Management (IWFM) of Bangladesh University of Engineering and Technology, Dhaka in partial fulfillment of the requirements for the degree of **Master of Science in Water Resources Development**

INSTITUTE OF WATER AND FLOOD MANAGEMENT

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY

November, 2015

INSTITUTE OF WATER AND FLOOD MANAGEMENT

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY

The thesis titled **'Index Based Climate Vulnerability Assessment for Hatiya of Noakhali of Bangladesh'** submitted by Md. Nahid Hasan Raju, Roll No. M1009282014P, Session October 2009, has been accepted as satisfactory in partial fulfillment of the requirement for the degree of Master of Science in Water Resources Development on November 28, 2015.

BOARD OF EXAMINERS

.....

Dr. A. K. M. Saiful Islam
Professor
IWFM, BUET, Dhaka
(Supervisor)

Chairman

.....

Director
IWFM, BUET, Dhaka

Member (Ex-officio)

.....

Dr. Sujit Kumar Bala
Professor
IWFM, BUET, Dhaka

Member

.....

Dr. Syed Hafizur Rahman
Professor
Department of Environmental Sciences
Jahangirnagar University, Savar, Dhaka.

Member (External)

CANDIDATE'S DECLARATION

It is hereby declared that this thesis or any part of it has not been submitted elsewhere for the award of any degree or diploma.

.....

Md. Nahid Hasan Raju

Dedicated to the

People of Hatiya

ACKNOWLEDGEMENT

I am privileged to take the opportunity to thank those who made it possible for me to complete this thesis. First and foremost, I would like to show my deepest gratitude to Almighty Allah.

I am extremely grateful to my supervisor, Dr. A. K. M. Saiful Islam, Professor, Institute of Water and Flood Management (IWFM), Bangladesh University of Engineering and Technology (BUET), Dhaka for his perpetual encouragement, generous help and support to made this study done through developing my knowledgebase, problem solving clue giving and experience sharing in this thesis work planning, designing and execution. His guidance and advices during this research work are sincerely appreciated. His visions on research methods and incredible supervision skills has made this task a significant degree less difficult than it could have been.

I am grateful to Ms. Martha Y. Aguilar, Office of the Minister of the Environment and Natural Resources, El Salvador for her outmost support through providing me the project report on climate vulnerability assessment in El Salvador. I am very grateful to Dr. Syed Hafizur Rahman, Professor, Department of Environmental Sciences, Jahangirnagar University, Dr. G.M. Tarekul Islam, Professor and Director and Dr. Sujit Kumar Bala, Professor, IWFM, BUET for their valuable time to serve as examiner for this research.

I am very much thankful to Swapan Chandra Dey and Md. Oli Uddin for their support as field enumerator to carry month-long field survey and also for their thoughts and experiences to develop the questionnaire. I want also express my gratitude to Md. Shariful Islam, Research Officer, Climate-Resilient Ecosystems and Livelihoods (CREL) Project for his contribution in developing the maps of this study. Special thanks to Md. Golam Rabbani Fahad, Research Assistant, IWFM, BUET, for his support in getting the model data and associated process.

I am deeply grateful to the all respondents and anonymous persons of Hatiya who have made their contribution to this research.

ABSTRACT

Climate change is the major threat to Bangladesh, and the elongated coastline is the primary victim of the climate extremes. Geographically Bangladesh is at critical location to be vulnerable to climate change. The impact of climate change has been increasing day by day, and the measuring local impact or vulnerability is essential to plan coping strategy. At global scale, there are several tools and techniques to measure vulnerability, whereas country specific tool is absent for Bangladesh. For developing an effective tool to measure vulnerability, Hatiya was selected to conduct the study as vulnerable location. The method of quantifying climate vulnerability index (CVI) has two separate parts- a) assessing the exposure (climate threat) by analyzing historical and regional climate model data, b) the other part is assessing the resilience and adaptability through participatory process and their future projections. Impact of climate change or the climate threat index (CTI) or exposure is calculated from observed (historical) and model data for baseline (2010) and projected 3 future so called time-slices of each 30 years period (i.e. 2020s, 2050s, and 2080s). The participatory results for resilience and adaptability are also projected to the same timeslices. Finally, the CVI is measured with a comprehensive empirical formula using the all three sub-indices. The results are denoted in the scale of 0 to 1, which means the minimum value of CVI could be 0 and the maximum value could be 1.

The result of this study coincides with the general perception of vulnerability. The value of CVI from observed data is similar to the model data. On the other hand, model data have given regular incremental trends of CVI for a particular location. The least vulnerable location of Hatiya is Sonadia and most vulnerable location is Nalchira. Physical exposure and socio-cultural cohesions were the major impacted factors for determining CVI for different locations of Hatiya. The study also revealed that better access to resources or facilities does not necessarily mean that the locations are less vulnerable and have high adaptability and resilience because the socio-cultural and natural variables have significant impacts on vulnerability. This comprehensive approach may be used to assess the vulnerability of data-scarce communities or systems for designing initiatives to reduce the vulnerability of climate change.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS AND ACRONYMS

A	Adaptability
BCCSAP	Bangladesh Climate Change Strategy and Action Plan
BMD	Bangladesh Meteorological Department
CAGR	Compound Annual Growth Rate
CDD	Consecutive Dry Days
CEI	Climate Extremes Index
CS	Cyclone Shelter
CREL	Climate-Resilient Ecosystems and Livelihoods
CTI	Climate Threat Index
CVI	Climate Vulnerability Index
DMB	Disaster Management Bureau
E	Exposure
ETCCDI	Expert Team on Climate Change Detection Index
FGD	Focus Group Discussion
GCM	General Circulation Model
GDP	Gross Domestic Products
IIASA	International Institute for Applied Systems Analysis
IPCC	Inter-governmental Panel on Climate Change
LGED	Local Government Engineering Department
LVI	Livelihood Vulnerability Index
NAPA	National Adaptation Programme of Action
R	Resilience
RCP	Representative Concentration Pathways
SCS	Severe Cyclonic Storms
SRDI	Soil Research Development Institute
SSP	Shared Socioeconomic Pathways
UNFCCC	United Nations Framework Convention on Climate Change
WFD	Watch Forcing Data
WMO	World Meteorological Organization
WSDI	Warm Spell Duration Index

CHAPTER 1 : INTRODUCTION

1.1 Background and Present State of the Problem

Bangladesh is the most vulnerable country for climate change for its geographic location, high population density and natural resource dependency [1] made the country vulnerable. The geomorphology have made the country one of the most vulnerable one to climate change [2] and the Bay of Bengal along with its geographic location and climate exposure made the coastline lead to devastating losses of lives and property due to the surge from storm of even moderate intensity [3]. Bangladesh and India suffer 86% of mortality from tropical cyclones, which occurs mainly during the rarest and most severe storm categories (i.e. Categories 3, 4, and 5 on the Saffir–Simpson scale) [4]. According to IPCC [5] coastal areas of Bangladesh are facing an increasing range of stresses and shocks, the scale of which now poses a threat to the resilience of both human and environmental coastal systems, and are likely to be exacerbated by climate change, similar statement are also found on NAPA [6] and BCCSAP [7]. Low-lying developing countries like Bangladesh is expected to face very high impacts and associated annual damage and adaptation costs of several percentage points of gross domestic products (GDP). Seawater inundation has become a major problem for traditional agriculture in Bangladesh [8].

Hence, it is essential to know the vulnerability of coastal area of Bangladesh using appropriate approach. Approaches that are currently used [9] [10] [11] to determine the climate vulnerability are usually index based and location specific. Application of these index based vulnerability assessment method needs spatial correction. A global Adaptation Policy Framework [12] and Aguilar et al., [13] and others have introduced several vulnerability assessment indices which were applicable to that spatial and temporal context. This study has been commissioned to develop a new approach or methods to assess climate vulnerability index in any location of the country. Primarily, considering resource and time limitation study was confined to sub-national level. Effectiveness of the method at sub-national level could promote to use this tool or method in other locations of Bangladesh.

1.2 Rationale of the Study

Currently the climate change is the major threat to Bangladesh [14] [15] and the coastal areas are more vulnerable to increasing climate change, but there is no proper database on climate vulnerability. Knowing the risk is the prior factor to adopt appropriate actions. Meghna Estuary is located in the south of Bangladesh and is one of the most dynamically deforming estuaries on the earth [16]. The Ganges, the Brahnmaputra, and the Meghna join together and find their way to the Bay of Bengal through Meghna Estuary and Hatiya is one of the largest coastal islands situated in the Meghna Eastuary. The morphology of Hatiya is changing very rapidly for high erosion rate in the northern part and high siltation rate in south-eastern part. These factors imposed the study to select Hatiya as study area. The climate vulnerability is very much visible at Hatiya and within the Hatiya the changes have very high contrast, which was another strong influencing factor for selection. The study topic was chosen to assess the climate vulnerability index starting from micro region. The development of methodological framework was thought to be a comprehensive tool to assess nationwide climate vulnerability. The tool development was assumed as outcome of the study. The above discussion have made the study rationale.

1.3 Objectives of the Study

The key objectives of the research are as follows:

1. To calculate the climate threat index of the research area.
2. To estimate the climate vulnerability index (CVI) and develop a climate vulnerability maps of research area.

1.4 Possible Outcomes of the Study

Undoubtedly it could be said from various scientific evidence and international reports that Bangladesh is the worse victim of changing climate. Various sectoral specialists and different organizations are struggling to quantify the impacts, but at present, there is no/limited type of tools to quantify the local level climate change impacts applicable for Bangladesh. From this study, it is expected to deliver a comprehensive method for climate change vulnerability assessment for identifying the present and future climate threats of Bangladesh. The vulnerability assessment results will help policymaker and researcher to take further initiatives for tackling impacts of climate change. Thus, it

could be an effective tool for climate change regional planning, through which within the country climate change hotspots will be under proper initiatives based on their vulnerability.

1.5 Limitations of the Study

The major limitations of the study are:

1. GDP Growth Rate: The projected GDP growth rate was taken from IIASA database which is for national level. Local GDP growth rate could have different scenario.
2. First Order Climate Change: The study has considered only the first order climate change impact associated with precipitation and temperature change. Secondary or tertiary level impact assessment could have more elaboration of local climate vulnerability.
3. Equal Weightage: In the Resilience and Adaptability measuring process each variables were assigned as equal weightage, instead of considering their actual contribution to resilience and adaptability.

1.6 Organizations of the Chapters

The thesis contains six chapters. The organization of the chapters is as follows- Chapter 1 provides the background of the study and present state of the problems. It also draws attention to the objectives of the study with limitations and organization of the chapters. Chapter 2 is the literature review, where the previous works are reviewed and some theoretical discussions were made to establish the concept. Chapter 3 have illustrated the study area through characterization of different features of interest. Chapter 4 discusses the methodology in detail used to assess the climate vulnerability index. This chapter is the major part of the study, where detail of the process to assess the baseline and future resilience, adaptability, climate threat, and as well as the climate vulnerability index were discussed thoroughly. Chapter 5 have described results of the baseline and future resilience, adaptability, threat, and vulnerability. The chapter has also revealed the governing factors of the above variables. Chapter 6 has given the concise and brief discussion on the overall finding of this study. It has also drawn some recommendation for further development of the study/methods.

CHAPTER 2 : LITERATURE REVIEW

2.1 Introduction

This chapter will provide a brief literature review on climate change, climate change vulnerability and present state of vulnerability assessment. Currently there is no standalone method for vulnerability measurement and scientists are trying to develop best fitted method. Last few decades, there were various researches to quantify the vulnerability of climate change at various location, but those methods were applicable for those specific regions/locations. In addition, a brief description of some other important components of climate change risk reduction elements are presented in this chapter.

2.2 Climate Change and the Drivers

"Climate" in a narrow sense is usually defined as the "average weather", or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period is 30 years, as defined by the World Meteorological Organization (WMO). These quantities are most often surface variables such as temperature, precipitation, and wind. Climate in a wider sense is the state, including a statistical description, of the climate system [17]. Classical climatology provides a classification and description of the various climate regimes found on Earth. Climate varies from place to place, depending on latitude, distance to the sea, vegetation, presence or absence of mountains or other geographical factors. Climate varies also in time; from season to season, year to year, decade to decade or on much longer time-scales [18].

According to the IPCC's (2013) [19] latest assessment report climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land use. Note that the Framework Convention on Climate Change (UNFCCC),

in its Article 1, defines climate change as: *'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods'*. The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition, and climate variability attributable to natural causes [19]. Changes in climate may be due to natural processes or to persistent anthropogenic changes in atmosphere or in land use. Note that the definition of climate change used in the United Nations Framework Convention on Climate Change is more restricted, as it includes only those changes which are attributable directly or indirectly to human activity [20].

In the earlier report of IPCC (2001) climate change is defined as a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer) [17].

2.2.1 Climate Change Scenario

The name "representative concentration pathways" was chosen to emphasize the rationale behind their use [21]. Representative Concentration Pathways (RCPs) are four greenhouse gas concentration trajectories adopted by the IPCC for its fifth Assessment Report (AR5) in 2014 [22]. RCPs are referred to as pathways in order to emphasize that their primary purpose is to provide time-dependent projections of atmospheric greenhouse gas (GHG) concentrations. In addition, the term pathway is meant to emphasize that it is not only a specific long-term concentration or radiative forcing outcome, such as a stabilization level, which is of interest, but also the trajectory that is taken over time to reach that outcome. They are representative in that they are one of several different scenarios that have similar radiative forcing and emissions characteristics.

Four RCPs has been produced from IAM scenarios: one high pathway for which radiative forcing reaches >8.5 W/m^2 by 2100 and continues to rise for some amount of time; two intermediate "stabilization pathways" in which radiative forcing is stabilized at approximately 6 W/m^2 and 4.5 W/m^2 after 2100; and one pathway where radiative forcing peaks at approximately 3 W/m^2 before 2100 and then declines. The pathways

are used for climate modeling and research. They describe four possible climate futures, all of which are considered possible depending on how much greenhouse gases are emitted in the years to come. The four RCPs are RCP2.6, RCP4.5, RCP6, and RCP8.5, are named after a possible range of radiative forcing values in the year 2100. All the four RCPs atmospheric CO_2 concentrations are higher in 2100 relative to present day as a result of a further increase of cumulative emissions of CO_2 to the atmosphere during the 21st century [23].

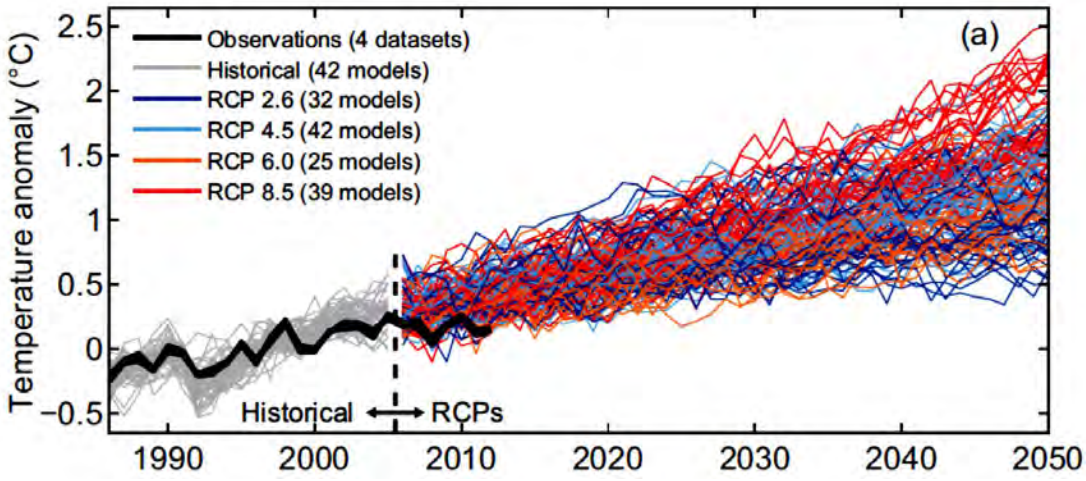

Figure 2.1: Global mean temperature near-term projections relative to 1986−2005.

2.3 Assessing Vulnerability

2.3.1 Adaptability

Adaptability is the capacity of actors in a system to influence resilience [24]. Adaptability or adaptive capacity is the ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences [25]. Therefore the adaptability is the factor which can indicate the strength of certain systems to withstand against climate shocks.

2.3.2 Vulnerability

Vulnerability was a concept used first by engineers to assess the risk of building collapse and other problems [26]. The vulnerability is defined by the several researcher according to their perception. Kasperson *et al.* (2000) defined vulnerability as *the*

degree to which an exposure unit is susceptible to harm due to exposure, to a perturbation or stress, in conjunction with its ability (or lack thereof) to cope, recover, or fundamentally adapt (become a new system or become extinct) [27]. UN Department of Humanitarian Affairs defined vulnerability as *degree of loss (from 0% to 100%) resulting from a potential damaging phenomenon* [28]. IPCC (2001) defined it as *the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes* [29]. In the latest report of IPCC (2014) vulnerability is defined as *the propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt* [25]. Among the others Adger (2004) perception about vulnerability of a system, population or individual to a threat relates to its capacity to be harmed by that threat [30]. The conditions determined by physical, social, economic, and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards [20]. From the above discussions it is clear that the vulnerability refers to state of a system in which it could be affected by external changes and the vulnerability explicitly or implicitly refers to the biophysical and social vulnerability.

2.3.3 Resilience

The capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation [25]. In other words, amount of change a system can undergo without changing state [29].

2.3.4 Exposure

The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected [25]. Exposure of climate threat is the actual risk to the certain community. Exposure to climate variation is primarily a function of geography [31]. For example, coastal communities will have higher exposure to sea level rise and cyclones, while communities in semi-arid areas may be

most exposed to drought. In this study exposure hereinafter will be referred as climate threat.

2.4 Climate Change Detection Index

Climate change and extremes have become one focus of climate research [32] [33] [34] [35] [36], and several international conferences have been organized to stress these hot topics. There is a general consensus within the climate community that any change in the frequency or severity of extreme climate events would have profound impacts on nature and society. It is thus very important to analyze extreme events. The monitoring, detection and attribution of changes in climate extremes usually require daily resolution data. Consequently, the ET (Expert Team) and its predecessor, the CCl/CLIVAR Working Group (WG) on Climate Change Detection have been coordinating an international effort to develop, calculate, and analysis a suite of indices so that individuals, countries, and regions can calculate the indices in exactly the same way such that their analyses will fit seamlessly into the global picture [37] [38]. Climate extremes include heavy precipitation, floods, heat waves, droughts, storm surges, and hurricanes, among many others. The Climate Extremes Index (CEI) proposed by Karl *et al*. [10] have been used to indicate the overall extreme situations of the climate. In 2009 World Meteorological Organization (WMO) published a guideline to calculate climate extremes. In that guideline Expert Team on Climate Change Detection Indices (ETCCDI) recommended 27 core climate indices [39] were identified to calculate climate extremes.

2.4.1 Climate Change Core Indices

ETCCDI recommended core indices are the basic indices to measure climate extremes. These indices are being used to serve various purposes to detect the extreme values globally. Based on those indices user communities are proposing customized indices for different specified purposes [40] [41]. 27 climate change core indices are appended in Annexure-2.

2.4.2 Shared Socioeconomic Pathways

In the climate research a new framework has been developed to facilitate the production of integrated scenarios based on combinations of climate model projections,

socioeconomic conditions, and assumptions about climate policies [42]. In the recent past, we had climate model for assessing the future climatic changes, but, for assessing the socioeconomic changes there was no framework to work with. Recent studies have been focusing on the socioeconomic aspects of climate change. O'Neill *et al.* (2014) in their study has been introduced a concept of "Shared Socioeconomic Pathways (SSPs)" in climate research. The SSPs have been defined by O'Neill *et al.* (2014) *plausible alternative trends in the evolution of society and natural systems over the 21st century at the level of the world and large world regions. They consist of two elements: a narrative storyline and a set of quantified measures of development* [42]. The study has conceptualize five SSPs along with the climate scenarios. Table 2-1 is the description of the five SSPs with the challenges for future climate policies.

Table 2-1: Initial starting points for SSP narratives and their challenges for Climate Change [42]

SSP	Challenges	Illustrative Starting Points for Narratives
SSP 1	Low for mitigation and adaptation	Sustainable development proceeds at a reasonably high pace, inequalities are lessened, technological change is rapid and directed toward environmentally friendly processes, including lower carbon energy sources and high productivity of land.
SSP 2	Moderate	An intermediate case between SSP1 and SSP3.
SSP 3	High for mitigation and adaptation	Unmitigated emissions are high due to moderate economic growth, a rapidly growing population, and slow technological change in the energy sector, making mitigation difficult. Investments in human capital are low, inequality is high, a regionalized world leads to reduced trade flows, and institutional development is unfavorable, leaving large numbers of people vulnerable to climate change and many parts of the world with low adaptive capacity.
SSP 4	High for adaptation, low for mitigation	A mixed world, with relatively rapid technological development in low carbon energy sources in key emitting regions, leading to relatively large mitigative capacity in places where it mattered most to global emissions. However, in other regions development proceeds slowly, inequality remains high, and economies are relatively isolated, leaving these regions highly vulnerable to climate change with limited adaptive capacity.
SSP 5	High for mitigation, low for adaptation	In the absence of climate policies, energy demand is high and most of this demand is met with carbon-based fuels. Investments in alternative energy technologies are low, and there are few readily available options for mitigation. Nonetheless, economic development is relatively rapid and itself is driven by high investments in human capital. Improved human capital also produces a more equitable distribution of resources, stronger institutions, and slower population growth, leading to a less vulnerable world better able to adapt to climate impacts.

2.4.3 Climate Vulnerability Index Global Perspective

Index based assessment of climate extremes has been started since nineties, when the global climate community felt the need to measure the climate extremes homogenously throughout the world. The work started with Karl *et al.'s* [10] development Climate

Extreme Index (CEI) for United States. Later on when climate community identified core climate change indices the process got pace in further development.

Climate Vulnerability Index (CVI) was first used by Sullivan and Meigh in 2005 [26]. The CVI study was published on Water Science and Technology in their 51 volume. It was a comprehensive process to assess climate vulnerability. In that time, the study had introduces state of art technology. The major limiting issues of the study are dependency on different data sources and construct scenario for climate change based GCM outputs. Sullivan method was time bound process, which can only assess the present vulnerability.

Later on several methods were suggested by different scientist for assessing vulnerability. Among them Füssel & Klein (2006) [43], Füssel (2007) [44], Hahn *et al.* (2009) [45], and Aguilar *et al.* (2009) [13] are cited in this study.

This study is taken as part of further development of Aguilar *et al.* (2009) suggested method. In their study they have identified a comprehensive process to assess climate vulnerability index (CVI). Their suggested equation was taken as baseline for further development. The equation has the three independent variables called Exposure (E), Resilience (R), and Adaptability (A). The limitations of that study was to measure the exposure of climate threat index. In that study baseline exposure and future state has been determined through the analysis of five indicators (Recurrence of an extreme dry year; Recurrence of an extreme wet year; Maximum number of consecutive days when the rain >40mm; Recurrence of periods of consecutive dry days >11 days during July and August; Annual maximum temperature rise during a drought yearend), but the missing part is the calculation process which is not clear for further replication. For the future projection of E was done based on some predetermined assumptions, which were very much confined to a certain geography. In case of R and A, future projection methods were not clear enough for replication. They were contacted to understand the processes for assessing CVI, but no response were found.

Based on the above citation, this study was taken to elaborate and develop the CVI detection process, especially for Bangladesh. The limitations of Aguilar *et al.* (2009)

were addressed in this study through using the SSP and dynamically downscaled concepts.

2.4.4 Climate Vulnerability Index in Bangladesh

There are no published evidences to support the statement that in Bangladesh Climate Vulnerability assessment has been done in similar fashion. Few evidences were found in different citations [15] [46] where vulnerability of Bangladesh was addressed in a descriptive manner. In recent time, few studies were carried out using the secondary techniques like the livelihood vulnerability index (LVI) [47]. The results have been found in this report is negative (LVI is -0.06) which mean that there were no climate vulnerability at that time. This results proved that the LVI is not appropriate for Bangladesh perspective. Few oral evidences were found that the processes of climate vulnerability assessment is under process within the development organizations. As a researcher these cited evidences have motivated to take Climate Vulnerability Index (CVI) assessment as a research topic.

CHAPTER 3 : CHARACTERIZATION OF THE STUDY AREA

3.1 Socio-Economic Background

3.1.1 Location

Noakhali, one of the largest riverine deltaic districts is located between 22°07′ and 23°08′ North latitudes and 90°53′ and 91°27′ East longitudes at the fringe of the Bay of Bengal (Map 3.1 a). The total area of this district is 3,600.99 sq. km. [48], which is about 2.44 of the country [49]. About 22% of its surface area comprises by tidal rivers namely – Meghna, Hatiya, Bamni and Burirchar. The salinity in the river water and soil varies with the season, i.e., least during rainy season and high in dry season [49]. According to the basic characteristics to classify a coastal region such as impact of tide, sea water intrusion and cyclone or surge, Companigonj, Hatiya Noakhali Sadar are categorized as “Exposed Coast” [49]. This signifies vulnerability of Hatiya Upazila. Hatiya Upazila (Map 3-1 b) has an area of 1508.23 sq km [50], and is surrounded by Noakhali Sadar and Ramgati upazilas on the north, Bay of Bengal, on the south and the east, Manpura upazila on the west. This upazila consists many big and small offshore islands [50].

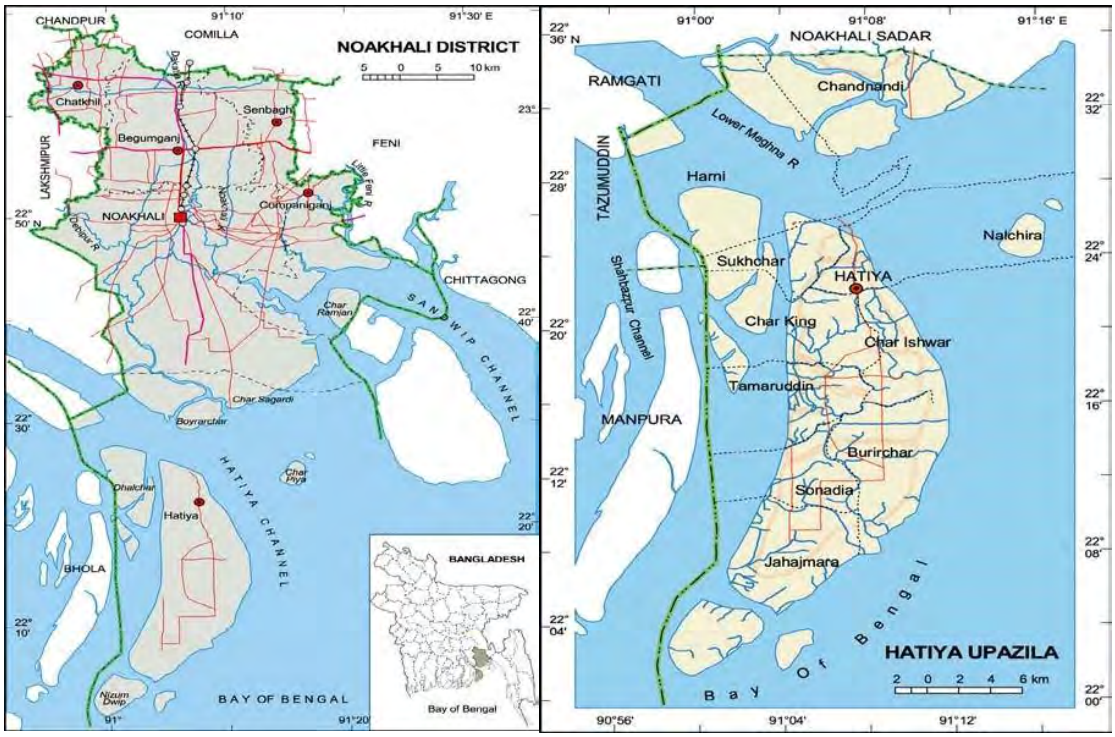

Figure 3.1: (a) Physiographic sketch out of Noakhali district; (b) Hatiya upazila

3.1.2 Administrative Setup

Noakhali district has 6 Upazilas, 45 wards, 90 Mahallas, 83 union Parishads, 909 Mouzas and 978 villages [50]. The Upazila consists of 10 Union Parishads, 34 Mouzas and 62 villages. The details of the administrative units are listed on the Table 3.1 [48]:

Table 3-1: Upazila and Unions of Noakhali district

Sl	Upazila	Pourashava	Union	No of Wards	No of Mouzas	No of Villages
1	**Hatiya**	None	Sukchar, Burirchar, Chandnandi, Char Ishwar, Char King, Harni, Jahajmara, Nalchira, Sonadia, Tamaruddin	None	34	62
2	Noakhali Sadar	Noakhali, Kabirhat	21 unions	18	276	284
3	Begumganj	Chowmuhani	25 unions	9	325	347
4	Chatkhil	Shatkhil	10 unions	9	108	129
5	Companiganj	Companiganj	7 unions	9	35	44
6	Senbagh	None	9 unions	None	99	111

3.1.3 Demography

3.1.3.1 Population

Based on the population census of 2001 [48], Hatiya Upazila has a population of about 341,176 with a density of 226 person/Sq. km, which is less than that of Bangladesh (839/Sq. Km) as well as coastal area average (743/Sq. Km). The male to female ratio (per hundred) is 105 which is greater than other coastal areas. Total number of households is 66,728 [48] and average household size is 5.13. The Muslim population is about 87.16%, followed by Hindu (12.31%) [48].

Percentage distribution of population by age and sex class is given in Figure 5 based on population census data of 2001 [48]. If we consider age groups ‘below 14’ and ‘above 60’ as dependent, then age group distribution of Hatiya indicates that 53% (Figure 3.1) of the population is dependent i.e., more than half of the population. Generally it is considered that the higher the dependent population, the less the adaptive capacity.

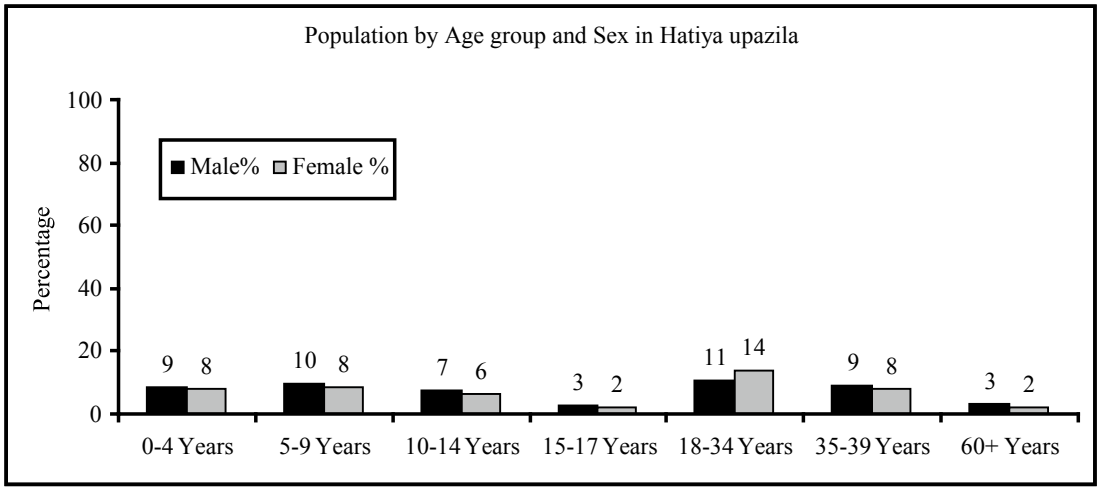

Figure 3.2: Population by Age group and Sex in Hatiya Upazila

3.1.3.2 Household structure

The structure of the dwelling households in Hatiya upazila are mostly "kutcha" type and almost 30% is can be called shanty type structure. Percentage distribution of households by type of housing structures is given in the Figure 3.2.

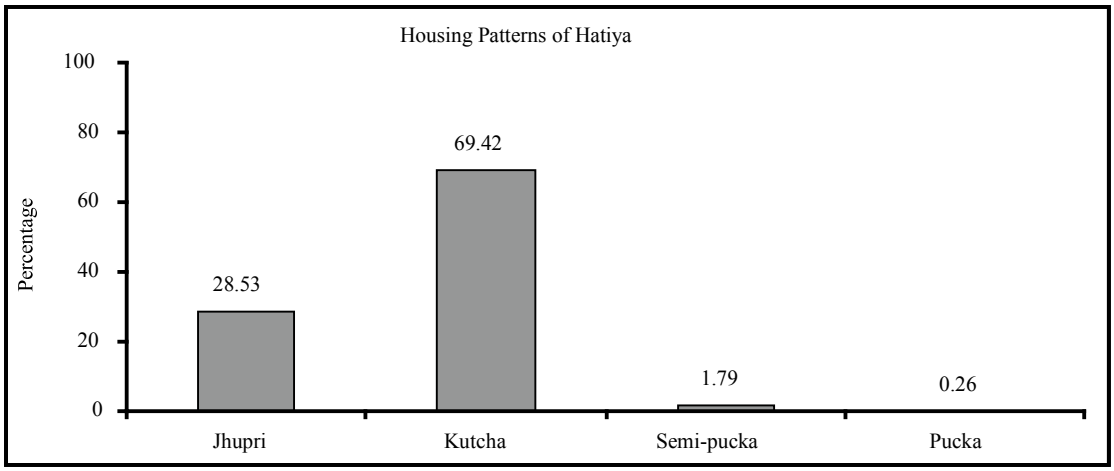

Figure 3.3: Household structure of Hatiya Upazila

3.1.3.3 Education

The literacy rate of the population at 7 years of age and over in Hatiya is less than that of Coastal Areas and Bangladesh average [49]. This literacy (Figure 3.3) may be obstructive to enhance awareness level or to sensitize the population on climate change, its vulnerabilities and adaptation needs. This will also be in disadvantage in adapting new technologies to reduce vulnerabilities.

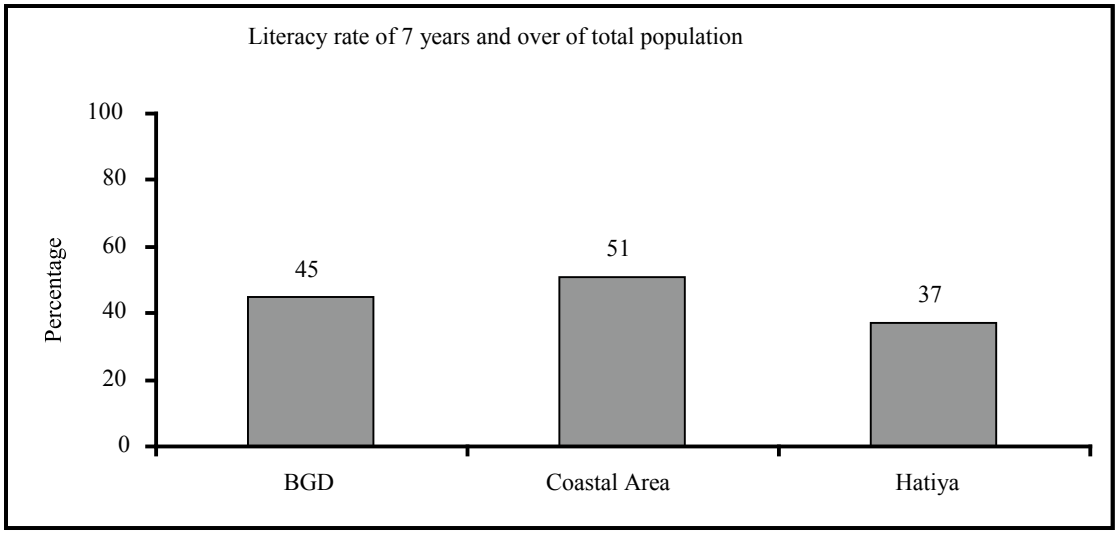

Figure 3.4: Literacy rate of 7 years and over of total population

3.1.3.4 Income

Information on income at the Upazila level was not found available. However, the district level data [49] exhibits (Figure 3.4) that per capita average income (Taka 13,938 per year) is lower than that of Bangladesh average (Taka 18,269 per year) or that of the coastal area average (Taka 18,198 per year). Such average income compared to other areas depicts economic constraint of Hatiya Upazila.

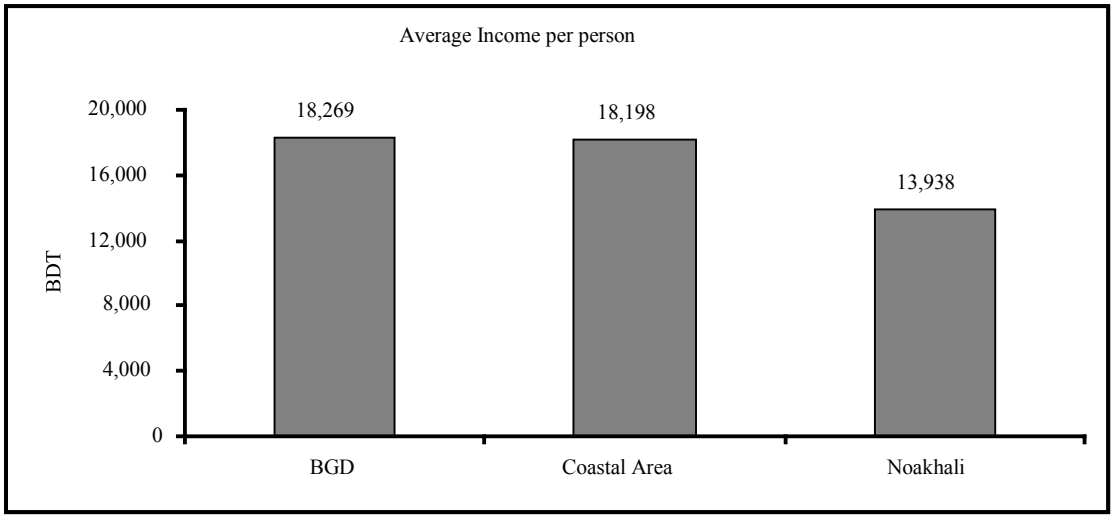

Figure 3.5: Average Income in Taka per person

Majority of the income source of the households is from agricultural sector (60%), either as farmer or as agricultural-labor (Figure 3.5) [49]. Despite a coastal area, fishery

provides income of only 7.24% household. Service and Business are the third and fourth highest sources of income and highest among the non-farming sources. High dependency on agriculture will contribute to the vulnerability to erratic climate variability and disaster.

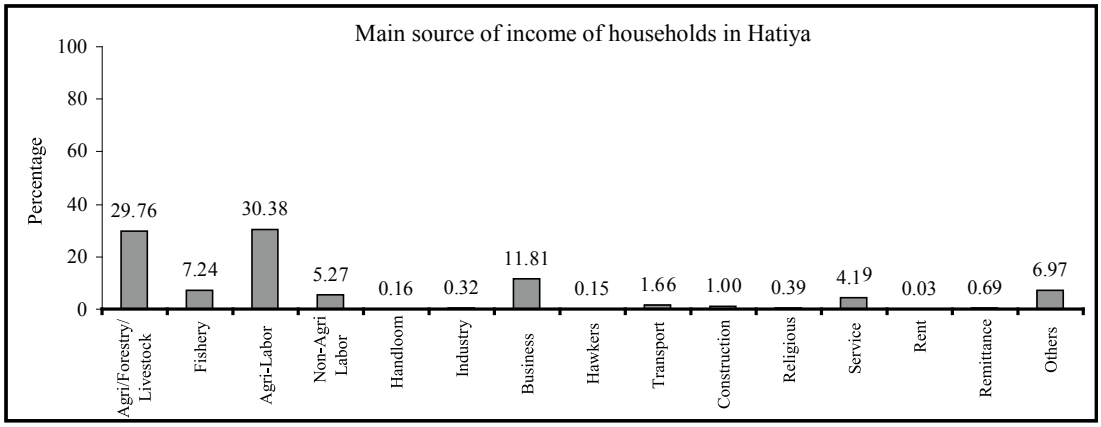

Figure 3.6: Main source of income of households in Hatiya

3.1.3.5 Ownership of Agricultural Land

The total agricultural land under Hatiya upazila is 28,982 hectares [49]. According to population census 2001 [48], about 45.03% households own agriculture land in the upazila. Due to unavailability of data, it is assumed that the rest (54.97%) households may have agricultural land in different ownership category (leased, khas etc) or without any agricultural land. Agriculture is the main source of income of the 65.38% households [48]. According to Uddin and Iftekhar (2005), percentage of agricultural land under single, double and triple cropping annually is 38%, 46% and 16% respectively. Compared to other upazilas of Noakhali [49], the Haitya upazila has the highest percentage (16%) of land under three cropping system. Thus the communities in Haitya Upzila are relatively in a less vulnerable situation if crop fails due to disasters. Generally, the multiple crop growers are comparatively better off, since they can somehow cope when one crop succumbs to a disaster. But sill this percentage is very poor to cope with disaster vulnerabilities.

3.1.3.6 Employment

The employment situation (of population more than 10 years) in Hatiya Upazila, Sukchar and Burirchar shows that the union is in worse position compared to the entire

Upazila. Unemployed percentage is high in Burirchar union and also is high dependency on agricultural activity in all three areas, rather less population is engaged in other activities (business, service sector and other activities). A large population (mostly women) is engaged in household works for both Upazila and union. Great potentiality exists if these populations can be trained and engaged in alternative income generating activities.

3.1.3.7 Water, Sanitation and Health Support Services

Safe drinking water in the Upazila is available for 87% households that includes deep tubewell and tubewell [48]. Only 13% of the population uses pond or other sources (See Figure 3.6). While drinking water infrastructure can be said well developed, on the other hand sanitary facility is poor for the Upazila and is worst is Union. Only about 18%, 22% and 11% of the households respectively in the Hatiya upazila, Sukchar and Burirchar union have sanitary latrine facility. Non-sanitary (pit latrine without ring slab or open pit) exists to about 68% of the Upazila and only 63% (Sukchar) and 76% (Burirchar) of the households at the union level. Fifteen and twelve percent of the households in Sukchar and Burirchar union simply do not have any latrine, i.e., use open field. The people of Hatiya Upazila have access to 1 Upazila health complex and 10 family planning center.

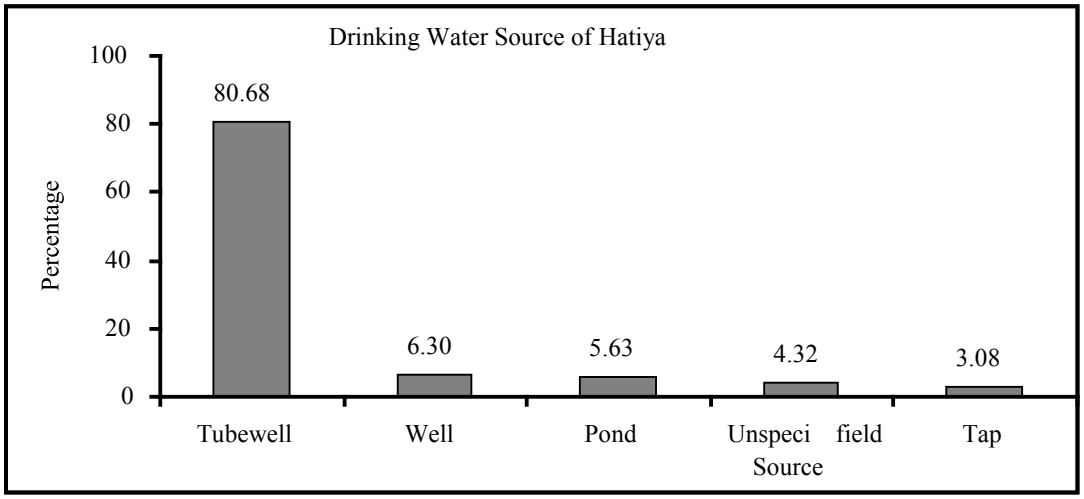

Figure 3.7: Drinking water source of Hatiya

3.2 Environmental Background

3.2.1 Climate

The climate of Hatiya is largely tropical and humid. Noakhali being a coastal district, the climatic features are very significant for it. The climatic variations are often hazardous and at times devastating. The metrological data collected at the Hatiya weather station, have been used for discussing the climatic features. Of all the climatic aspects we will try to consider only the rainfall, temperature and cyclone which are very important.

3.2.1.1 Rainfall

Generally the maximum rainfall occurs in July (698.7 mm), followed by June and August (Table 3.2) as per the data from BMD. Maximum number of rainy days occurs in July and August.

Table 3-2: Average normal (for 30 years) rainfall (in mm) and monthly rainy day for Hatiya

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Rainfall in mm	6.2	22.1	62.9	140.3	300.1	572	698.7	566.2	385	211	63	12.3
Monthly Rainy Day	1	2	3	7	14	18	20	21	15	7	3	1

Highest average rainfall (2691 mm) occurs (Table 3.2) in monsoon season (June, July, August & September), drops down to average 1459 mm in post-monsoon (October & November), and further decreases in winter period (December, January & February) then picks up once again in pre-monsoon (March, April & May).

Table 3-3: Seasonal total rainfall (mm) pattern over Hatiya (1966 to 2008)

Seasonal pattern	N	Range	Minimum	Maximum	Mean	Std. Error	Std. Deviation
Winter period	37	152	0.00	152.00	37.94	7.23	44.03
Pre-monsoon period	37	897	112.00	1009.00	446.51	33.85	205.92
Monsoon period	37	3259	29.00	3288.00	2333.48	103.42	629.11
Post monsoon period	37	762	0.00	762.00	297.62	30.14	183.33

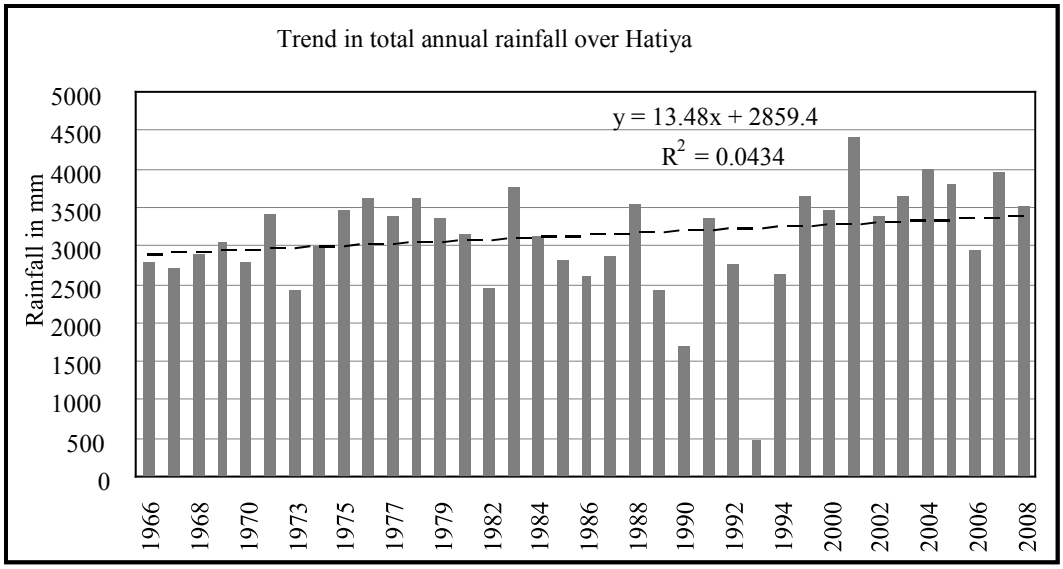

Figure 3.8: Trend in total annual rainfall over Hatiya

Total annual average rainfall calculated over 37 years period (1966 - 2008) is about 3047 mm per year with highest rainfall recorded 4431 mm in 2001 and lowest value in 1990 (Figure 3.7). Total annual rainfall over 37 year's shows increasing trend (dashed line in Figure 3.7) although not statistically significant. Seasonal total rainfall is shown in Table 3.3. Quadir & Iqbal (2008) further investigated the temporal variations and trends in rainfall (58 years from 1951-2007) for seasonal data of 9 coastal stations of which data for 4 relevant stations are shown in Table 3.4. Their study [51] shows decreasing trend of rainfall in monsoon and post monsoon and increasing trend in winter and pre monsoon at Chittagong compared to other three coastal stations, and the annual trend is less stronger compared to the other three stations.

Table 3-4: Trends (mm/decade; 1951-2007) of seasonal rainfall (mm) at 4 stations of the coastal zone

Station	Winter	Premonsoon	Monsoon	Postmonsoon	Annual
Bhola	**-4.1**	**-9.40**	**-52.20**	**-1.05**	**-66.00**
Barisal	**4.35**	**20.30**	**-10.50**	**-5.05**	**8.70**
Chittagong	**7.03**	**39.17**	**-14.32**	**-2.51**	**-5.25**
Hatiya (1967-2007)	**4.75**	**24.94**	**83.52**	**-0.51**	**140**
Note: Shaded box shows decreasing trend, white boxes shows increasing trend.					

Quadir et al. [52] found similar increasing trend of the pre-monsoon rainfall over other parts of the country only Bhola shows the decreasing trend and surmised that this is an indication of increasing activities of thunderstorm and rainfall in the coastal zone that can affect the movement of the fishing boats and fish catching thus disturbing the livelihood of the coastal fishermen.

3.2.1.2 Temperature

Being a coastal area, temperature data for Hatiya shows mild pattern (Table 3.5). Hottest month is May temperature up to 31.90C and the lowest temperature being 14.9 °C in January. The analyses of annual average maximum temperature indicate an increase and the annual average minimum temperature shows decreasing trend (Figure 3.8 and Figure 3.9). According to this trend, between 1966 and 2008 the temperature of the hottest month has increased by about 0.9º C on an average. This may be an indication of climate change phenomenon which may have already set in.

Table 3-5: Normal maximum and minimum temperature

Hatiya	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Maximum Temperature	25	27.4	30.6	32	31.9	30.5	29.8	30.1	30.8	30.8	29	25.8
Minimum Temperature	14.9	17.2	21.5	24.1	25	25.6	25.4	25.4	25.3	24.6	21.3	16.8

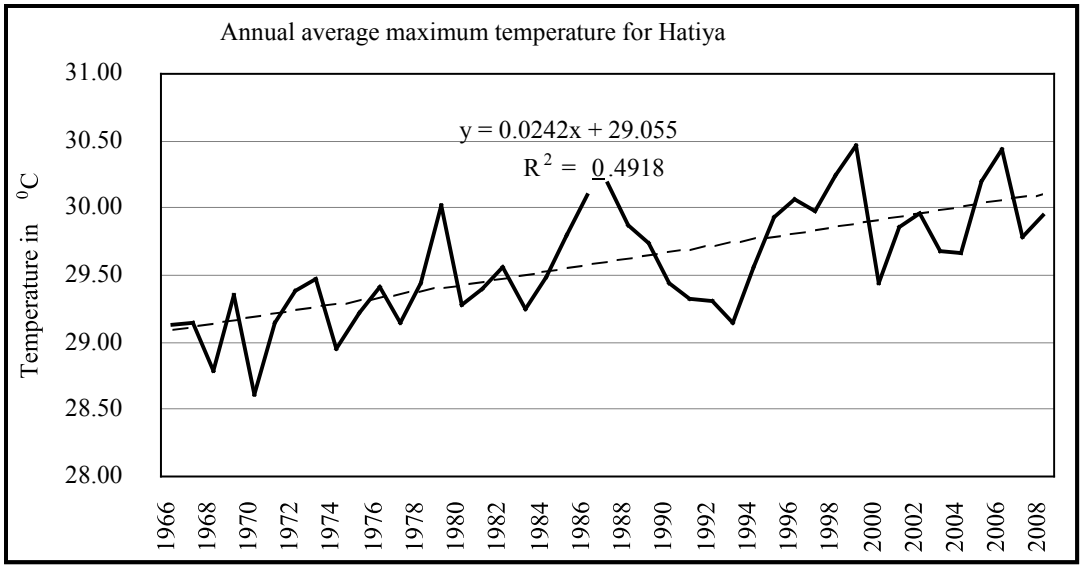

Figure 3.9: Trend in annual average maximum temperature (°C) over Hatiya

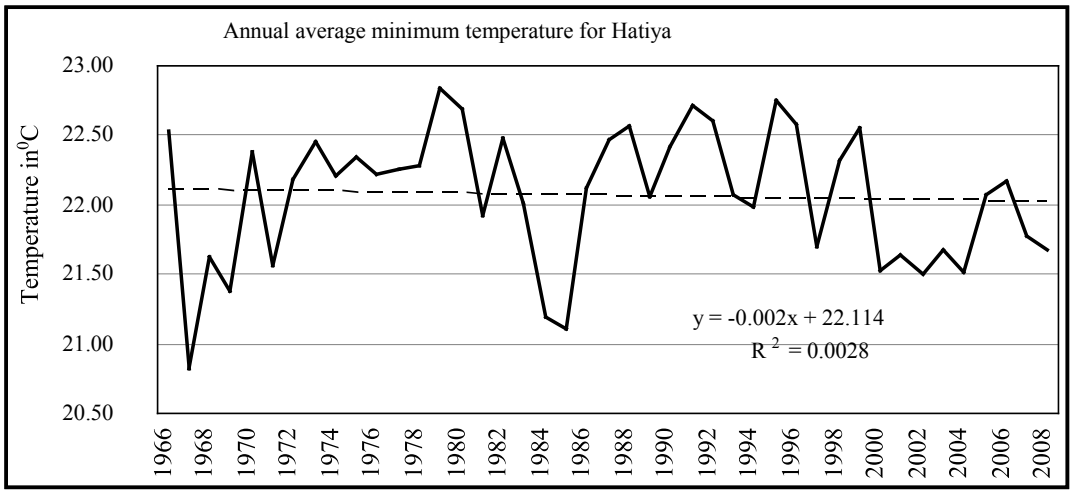

Figure 3.10: Trend in annual average minimum temperature (°C) over Hatiya

From Figure 3.8 and Figure 3.9, it is seen that the both maximum temperature shows increasing and minimum temperature shows decreasing trend especially starting from late 1984's and 2000's respectively. For Hatiya Quadir & Iqbal [51] have found that the annual trend in maximum temperature is higher than that of minimum temperature in all the cases.

3.2.1.3 Cyclone

Tropical cyclones are generally considered to be deadliest of all natural calamities. It causes huge loss of lives and properties and damage to environment with its strong wind force and associated tidal surges. Some of the statistics has already been described in the introductory chapter. Quadir & Iqbal [51] reported that in the Bay of Bengal for a period of 131 years (1877-2007), a total of 539 tropical cyclones were formed, i.e. an average of 4.1 tropical cyclones per year of which 1.7 belongs to intensive categories with wind speed higher than 88 km/hour. Table 3.6 below provides a classification of cyclonic disturbances for Bangladesh [53]. The categories 1-4 are pre-cyclone stages of the cyclonic disturbances. The tropical cyclone categories begin from the serial no. 5. A classification with the nomenclature of Super Cyclones are used for tropical cyclones having wind speed ≥ 220 km/hr but has not been officially introduced by BMD.

Table 3-6: Classification of tropical cyclones for Bangladesh

Sl	Types of disturbances	Wind speed (km/hr)
1	Low (L)	<31
2	Well-marked low(WL)	31-40
3	Depression (D)	40-50
4	Deep Depression (DD)	51-61
5	Cyclonic Storm (CS)	62-88
6	Severe Cyclonic Storm (SCS)	89-117
7	Severe Cyclonic Storm of hurricane intensity (SCS-H)	>117
Note: In the subsequent analysis Depression and Deep Depression are considered together as the category of Depression (wind speed 40-61 km/hr)		

It is found that during the period of 48 years (1960-2007), a total of 56 tropical cyclones hit the coast of Bangladesh of which 48.2 % are very strong cyclones (SCS-H), 17.9% are severe cyclonic storms (SCS) and the rests are CS.

Quadir & Iqbal [51] analyzing historical cyclone information found that, though the total number of disturbances is decreasing (Figure 3.10), the frequency of severe cyclonic storm with hurricane intensity is increasing (Figure 3.11) with reduced return period (Table 3.8).

Table 3-7: Sum, mean & STD of the frequency of tropical disturbances (1970-2007)

Categories	Total frequency	Mean	Standard deviation
D	141	4.15	2.50
CS	50	1.32	1.36
SCS (1974-2007)	24	0.71	0.80
SCS-H (1974-2007)	28	0.82	0.72
SCS+SCS-H	69	1.82	1.25
CS+SCS+SCS-H	119	3.13	1.65
All cyclonic disturbances	240	7.06	3.05
Source: adopted from Quadir & Iqbal (2008)			

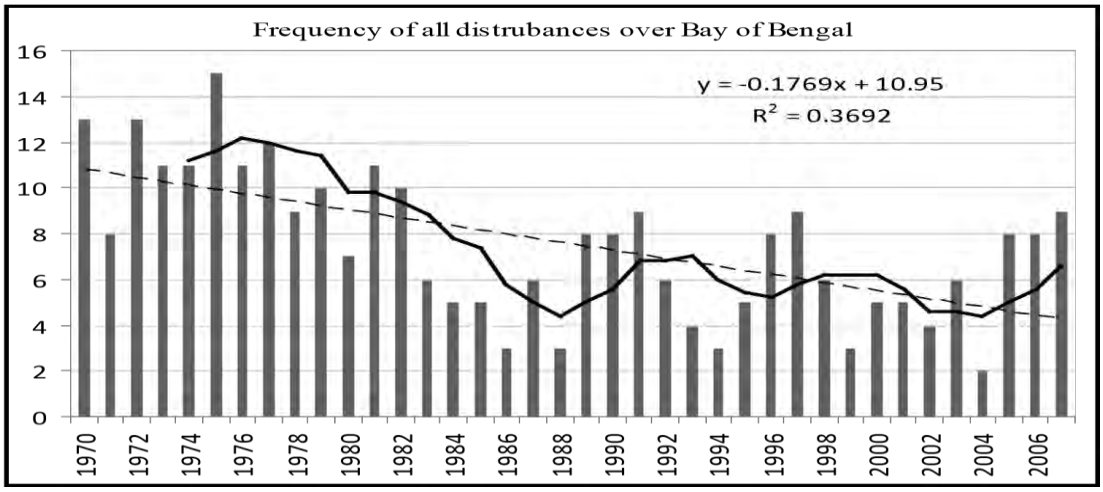

Figure 3.11: Frequency, trend & with 5 years moving average of all tropical disturbances over the Bay of Bengal

The 5 deadliest super cyclones generated in the Bay of Bengal have been shown in Table 3.8, of which one was formed in 1876 and is known as Great Bakergonj Cyclone and the other 4 had developed within the last 38 years. One is the 12 November, 1970 cyclone which hit Bhola coast of Bangladesh and had the return period of 94 years, another one is the 30 April, 1991 cyclone that hit the Noakhali-Chittagong coast and had the return period of 21 years and the other is the 29 October, 1999 cyclone that hit the Orissa coast and had the return period of 8 years. The last one is the Sidr, which hit the coast of Sundarban-Patuakhali on 15 November 2007 and had the return period of 8 years. This indicates that the number of highly intensive tropical cyclones has increased in the past 4 decades and their return period has also decreased.

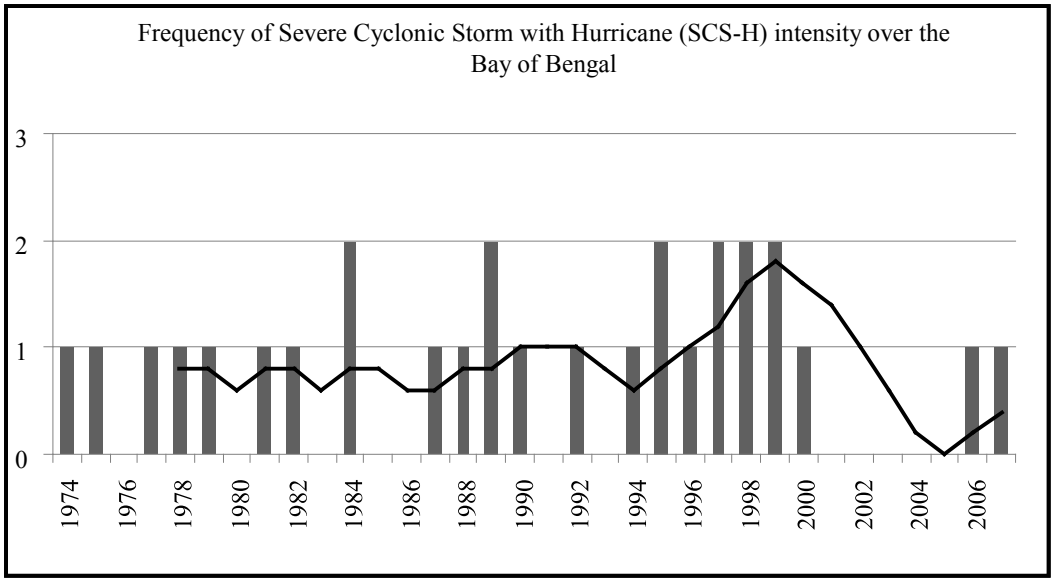

Figure 3.12: Frequency & 5 years moving average of Severe Cyclonic Storm with Hurricane intensity over the Bay of Bengal

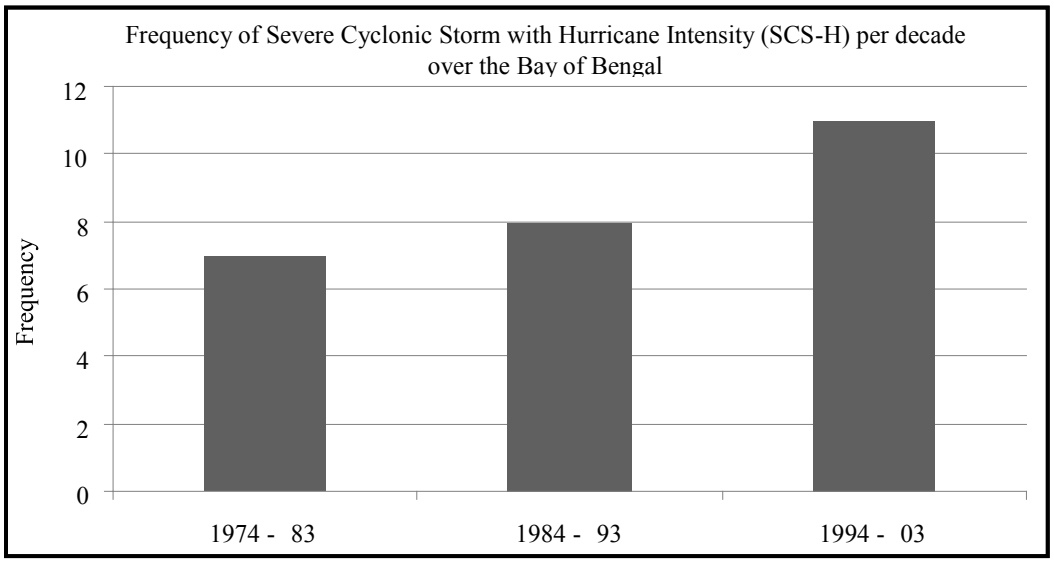

Figure 3.13: Decadal frequency of Severe Cyclonic Storm with Hurricane intensity over the Bay of Bengal

Table 3-8: Tropical cyclones of the Bay of Bengal with super cyclonic intensity (wind speed equal to or above 220 km/hr) and their characteristics

Year of incidence	Date of Occurrence and coast of landfall	Maximum wind speed (km/hr)	Storm Surges (m)	Return period (years)
1876	1 November Bakergonj (Meghna estuary) , Bangladesh	220	13.6	-
1970	12 November, Bhola, Bangladesh	224	10	94
1991	31 April, Noakhali-Chittagong, Bangladesh	235	8.8	21
1999	29 October, Orissa coast, India	225	7.8	8
2007	15 November Sundarban-Patuakhali, Bangladesh	240-250	6	8
Source: Quadir & Iqbal (2008)				

3.2.1.3.1 Cyclone Shelter

According to the Disaster Management Bureau (DMB) total number of cyclone shelter in Hatiya upazila is 132 (Table 3.9).

Table 3-9: Number of cyclone shelters in each union or ward of Hatiya Upazila

Name of the unions or wards of Hatiya upazila	Number of Cyclone Shelter
Burirchar	22
Chandnandi	1
Char Ishwar	25
Char King	17
Harni	8
Jahajmara	28
Nalchira	5
Sonadia	12
Sukchar	2
Tamaruddin	12
Total	132

Total capacity of these 24 cyclone shelters is 30,494 persons, i.e., 2 square feet per person. Local people during FGD however said that about 500 people can be

accommodated in a cyclone shelter which has around 1000 sq ft floor space. If we consider the capacity given by the government, then 54.263% out of 56,196 population can be accommodated using these 24 facilities. If 21 cyclone shelter is considered as 3 shelters are cyclone vulnerable than 47.26% of the population can be accommodated.

3.2.2 Environmental Issues

3.2.2.1 Salinity

Dry soil salinities were classified into the following groups of electric conductivity < 4 dS/m slightly saline 4-8 dS/m slightly to moderately saline 8-15 dS/m moderately to highly saline >15 dS/m highly saline. In Hatiya the salinity in soil is >15 dS/m, which indicates high saline. Salinities of <4 dS/m are within the tolerance of the commonly grown crops and vegetation of the area. The salinity level of 4 dS/m is considered as the threshold level (for soil salinity). SRDI report (2001) mentions a limit of 4 dS/m, above which salt tolerant varieties are required to be used.

Similarly in surface water an electric conductivity of 5 dS/m can be considered as tolerance limit for fresh water vegetation and fresh water aquatic communities. In Hatiya the surface water has a salinity of 5-10 dS/m. The Bangladesh standard for groundwater salinity is 600 mg Chloride/liter. As this value is widely exceeded in coastal areas, a more practical level of 1000 mg/l of Chloride has been suggested (ESCAP/UN, 1987). This would approximately correspond to a threshold of 2 dS/m (1000 mg/l Chloride solution generates EC of 1.5 to 2 dS/m at 20-300C). Ground water salinity in hatiya is 5-10 dS/m which is beyond the threshold limit [54].

3.2.2.2 Tide Inundation/ Tidal Water Movements

The annual average of daily water level fluctuations (differences between high and low water levels during a day) has been taken to characterize the coastal zone from the perspective of the criterion “tidal water movements”. The following classes would roughly represent different tidal zones with respect to this criterion:

< 0.3 m	range of daily fluctuations
0.3-1 m	regular tidal movements
1-2 m	strong tidal movements
>2 m	very strong tidal movements

The annual average water level fluctuation between high and low water during a tidal cycle of Hatiya is >2 m which resembles a very strong tidal movements [54].

3.2.2.3 Erosion and Accretion

The data of erosion and accretion [55] indicate that in Hatiya (Noakhali district) Upazila, the accretion is more than the erosion. These newly accreted sites are suitable for afforestation.

Table 3-10: Erosion and Accretion in the Coastal areas of Bangladesh between 1972 and 1991

Area	Erosion (sq. km)	Accretion (sq. km)
Sundarbans	74.73	14.45
Bhola area	69.63	329.49
Noakhali-Chittagong area	494.39	587.04
Cox's bazar	33.43	8.88

CHAPTER 4 : DATA AND METHODOLOGY

4.1 Introduction

For the development of integrated assessment of climate vulnerability of selected area, adopted a systemic approach, centrally incorporating the concept of complex adaptive system and applying through an interdisciplinary approach that integrates and combines theoretical conceptions of various knowledge. The study focused on developing a method for assessing climate vulnerability based on weather and socio-economic data. The study has two clearly delineated parts- one is climate threat (CTI) or exposure quantification from observed and modeled climate data and the other is resilience (R) and adaptability (A) calculation from field based primary data, which are collected using a close end questionnaire. The study is carried out within an integrated multidisciplinary approach for assessing current and future climate vulnerability for a defined territory.

4.2 Research Design

Research differs from field to field, approach to approach and nature of work. To determine the vulnerability to climate change of particular geographic area the research took a holistic move combining both time series data analysis derived from meteorological station(s) or climate model and local variable based data, collected by using questionnaire survey. Historical climate data (Bangladesh Meteorological Department) and dynamically downscaled climate modeled data (11 regional climate model) were used to determine baseline and future climate threats of the study area. Representative sociocultural, economic and natural environment data were collected through individual questionnaire survey to determine the resilience and adaptability of that particular study area.

4.3 Research Methodological Framework

The study is complex and requires a systematic methodology to answer the research questions/objectives (see Section 1.2). The overall study has been divided in some carefully sequential segments, provided in Figure 4.1.

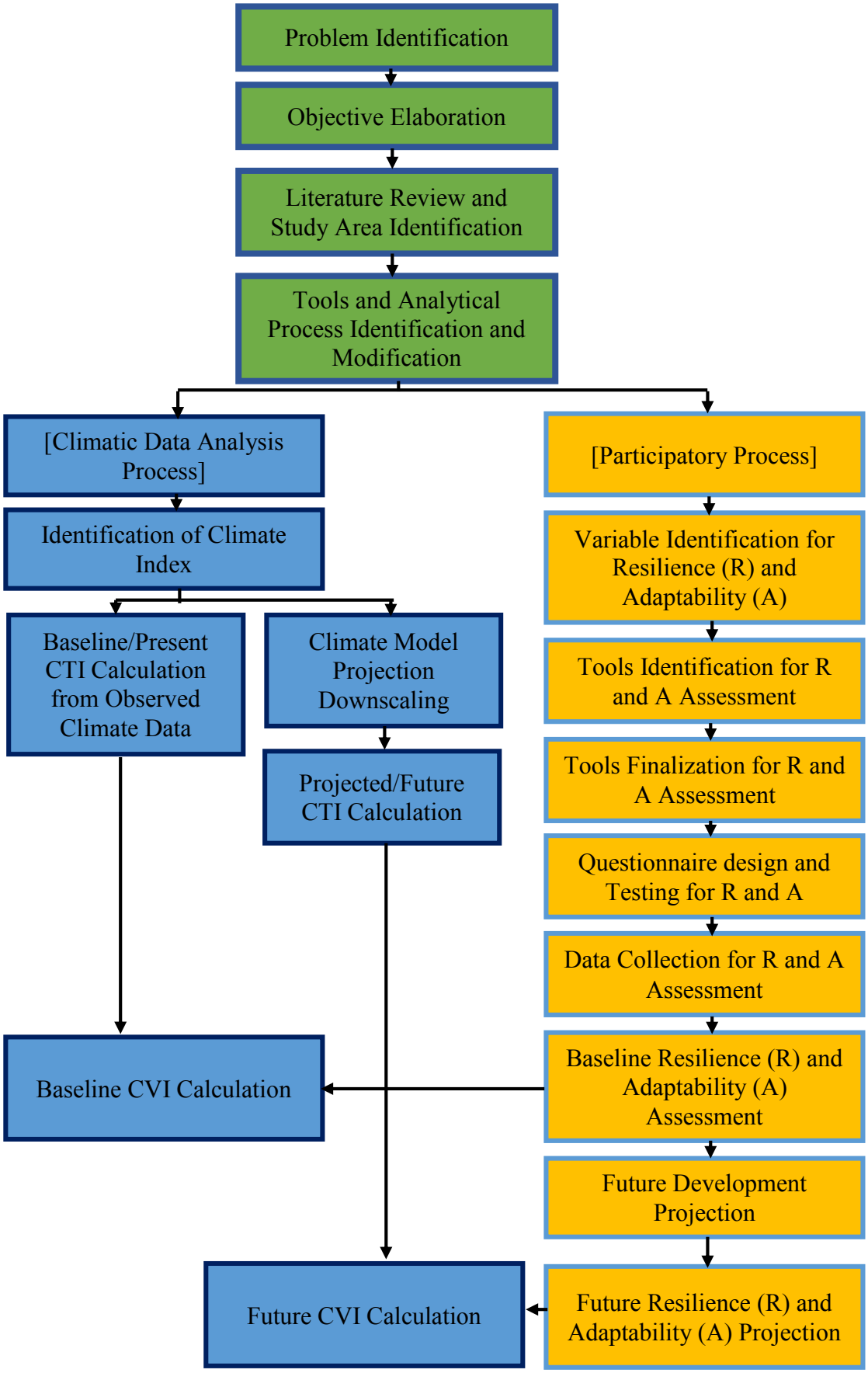

Figure 4.1: Research Methodological Framework

4.4 Data and Data Sources

The primary source of research observed weather data (daily precipitation, daily maximum and minimum temperature) is Hatiya Meteorological station for the period of 1966-2010. The missing data were replaced by the arithmetic mean of four peripheral Bangladesh Meteorological Department's stations, which are Bhola, Maijdeecourt, Sandwip and Sitakunda.

For the model data Regional Climate Model (RCM) data of latitude 22.25, and longitude 90.75 grid point were used in this study. The raw RCM output was retrieved from the repositories of Earth System Grid Federation (ESGF), the Indian Institute of Technology Madras (IITM) and from Swedish Meteorological and Hydrological Institute (SMHI). Details are provided in Table 4.1. The reference dataset used for the bias correction is the hybrid dataset of Watch Forcing Data - WFD [56] and the Watch Forcing Data methodology applied to ERA-Interim data (WFDEI) used in the Inter-Sectoral Impact Model Integration and Intercomparison Project ISI-MIP which combines forcing data of WFD (1901-1978) and WFDEI.GPCC (1979-2012). The bias correction methodology applied to the precipitation data is multisegment statistical bias correction [57]. For the rest of the climate variables, the same methodological principles are applied on different type of transfer functions due to differences in the data nature. As bias correction reference period, the 1981-2010 was considered. The 0.5° regular grid of WFD was used as reference. Among the four RCPs, the extreme scenario RCP8.5 is used for the analysis. Four time-slices are considered to represent the temperature and precipitation changes over Bangladesh. These time-slices are baseline 2010s (1981-2010), early era 2020s (2011-2040), mid era 2050s (2041-2070), long term era 2080s (2071-2100).

Table 4-1: Available biased corrected regional climate model data for RCP 8.5

Sl	Regional Model	hurs	pr	rlds	rsds	tas	tasmax	tasmin	wind
1.	WAS-44_CNRM-CERFACS-CNRM-CM5_r1i1p1_SMHI-RCA4_v2 _day	x	x	x	x	x	x	x	x
2.	WAS-44_ICHEC-EC-EARTH_r12i1p1_SMHI-RCA4_v2_day	x	x	x	x	x	x	x	x
3.	WAS-44_IPSL-IPSL-CM5A-MR_r1i1p1_SMHI-RCA4_v2_day	x	x	x	x	x	x	x	x
4.	WAS-44_MIROC-MIROC5_r1i1p1_SMHI-RCA4_v2_day	x	x	x	x	x	x	x	x
5.	WAS-44_MPI-M-MPI-ESM-LR_r1i1p1_MPI-CSC-REMO2009_v1_day		x	x	x	x	x	x	x
6.	WAS-44_MPI-M-MPI-ESM-LR_r1i1p1_SMHI-RCA4_v2_day	x	x	x	x	x	x	x	x
7.	WAS-44_NOAA-GFDL-GFDL-ESM2M_r1i1p1_SMHI-RCA4_v2_day	x	x	x	x	x	x	x	x
8.	WAS-44_ACCESS1-0_r1_CSIRO-CCAM-1391M_day		x				x	x	x
9.	WAS-44_CCSM4_r1_CSIRO-CCAM-1391M_day		x				x	x	x
10.	WAS-44_CNRM-CM5_r1_CSIRO-CCAM-1391M_day		x				x	x	x
11.	WAS-44_MPI-ESM-LR_r1_CSIRO-CCAM-1391M _day		x				x	x	x

Table 4-2: Climate Model Variable Description.

Sl	Climate Model Variable	Output Variable name	Comments	Unit	Intensity
1.	Near-Surface Relativ Humidity	hurs	This is the relative humidity with respect to liquid water for T> 0 C, and with respect to ice for T<0 C	%	Time mean
2.	Precipitation	pr	At surface; includes both liquid and solid phases from all types of clouds (both large-scale and convective)	$kgm^{-2}s^{-1}$	Time mean
3.	Surface Downwelling Longwave Radiation	rlds		Wm^{-2}	Time mean
4.	Surface Downwelling Shortwave Radiation	rsds		Wm^{-2}	Time mean
5.	Near-Surface Wind Speed	wind	This is the mean of the speed, not the speed computed from the mean u and v components of wind	ms^{-1}	Time mean
6.	Near-Surface Air Temperature	tas		K	Daily
7.	Daily-Maximum Near-Surface Air Temperature	tasmax	Monthly mean of the daily-maximum near-surface air temperature	K	Daily
8.	Daily-Minimum Near-Surface Air Temperature	tasmin	Monthly mean of the daily-minimum near-surface air temperature	K	Daily

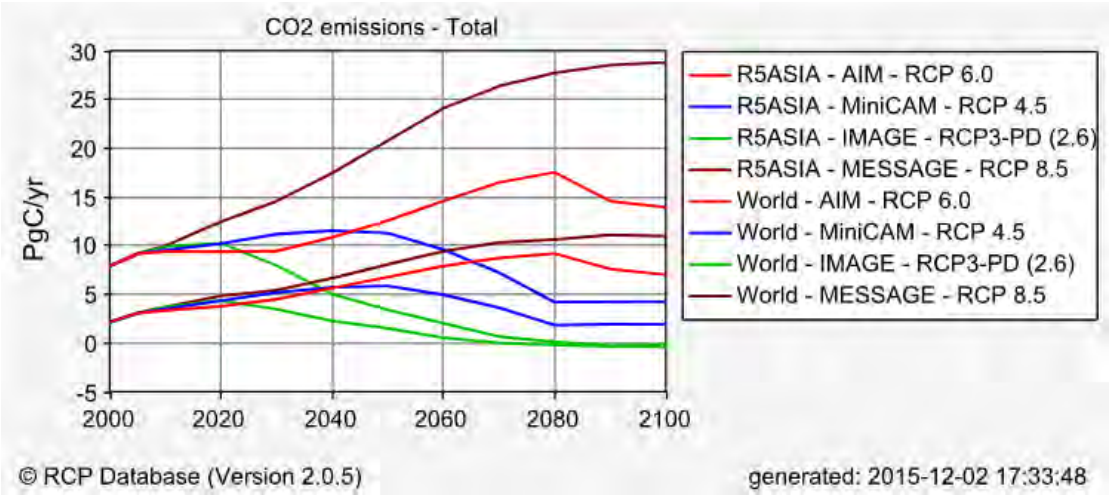

Figure 4.2: Global and Asian total CO_2 Emission Scenario over 21st Century through different RCPs based on IIASA's RCP Database

4.5 Development of Climate Vulnerability Index

Vulnerability shows shock and stress absorbing capacities of a community or a system in restoring their normal functions after disaster [59] [24]. The capacity denotes skills or ability of the community to deal with disaster [60] and to overcome and restore their functions after disaster by strategies and knowledge called 'resilience functions' or 'operational resilience' [61].

Assessing the current and future first order vulnerability due to climate change is the primary objective of the study. Many works has been done globally to assess the climate vulnerability and each of the works have developed different method for climate vulnerability. In this study only the first order vulnerability due to precipitation and temperature changes have been considered in assessing the exposure or threats. Their secondary and tertiary level impacts were not considered.

Climate change vulnerability is seen as the residual impacts of climate change after adaptation measures have been [24] implemented [12]. This concept of climate vulnerability has been evolved from the IPCC third assessment report (2001). The climate vulnerability is expressed in the following equation.

Vulnerability = Risk (predicted adverse climate impacts) – Adaptation

This is one of the early vulnerability relation accepted by the global community. Based on this relationship, many subsequent works have been made on climate vulnerability. Among the developments, Brooks [58] had suggested the vulnerability as a function of adaptive capacity defined as α, as the potential adaptation per unit time based on existing conditions, and adaptation as representing a reduction in vulnerability, which is also proposed by the IPCC equation, then potential vulnerability at time t, assessed at time t=0, can be expressed as:

$$V_p^t = V_0 - \alpha_0 t$$

Where, V_0 is current vulnerability (at t=0) and α_0 represents current adaptive capacity. He also suggested that if the adaptation is a function of adaptive capacity only then the expression will be at time t as:

$$V^t = V_0 - \int \alpha \, dt$$

In the above two equations of Brooks the primary determinant factor is adaptive capacity α. In those equations vulnerability is assessed from current vulnerability, but the current vulnerability measuring process is missing. With the advancement of time. vulnerability will be reduced due to increase adaptive capacity. In the future projection of vulnerability the impacts of other factors are not visible. Therefore, Brook's equations are supersede by this study.

Based on the vulnerability concept given by Smit *et al.* (1999) [59], Hahn *et al.* (2009) [45] developed the following equations to assess the household livelihood vulnerability index.

$$LVI = \frac{\sum_{i=1}^{7} W_{M_i} M_i}{\sum_{i=1}^{7} W_{M_i}}$$

$$LVI - IPCC = (e - a) * s$$

In their study, to assess the *LVI-IPCC* in IPCC framework approach identified seven contributing components under three categories, i) Exposure (Natural disasters and climate variability); ii) Adaptive Capacity (Socio-demographic profile, Livelihood strategies, and Social networks); and iii) Sensitivity (Health, Food, and Water). This study does not necessarily distinguish the resilience and its impacts on vulnerability. The seven contributing components are derived from questionnaire survey. There is no use of climate variability. Later on the method was some extent improved by Madhuri *et al.* (2014) [60]. To address the resilient in Hahn *et al.* (2009) [45] equation in addition they incorporated few more contributing components, which are- Natural Capital and other subcomponents (acquisition of skill, change in sowing and cropping schedules, loan taking, use of primary irrigation source, availability of immunization and

government and private hospitals, and toilet facilities) without changing the equations. As the resilience is not clearly distinguished in the original equation, therefore, its influence on vulnerability still undermined. The time after the IPCC 4th Assessment Report the researcher shifted the earlier concept to vulnerability, resilience and adaptation framework.

According to Bruneau *et al.* (2003) [61], the important features of resilience are robustness, rapidity, resourcefulness and redundancy. Robustness refers to the capacity to confront, resist and surmount the shock and distress without losing functionality. Rapidity refers to the pace at which households and the community rise over disruption and is capable of avoiding future loss.

Resourcefulness indicates diversity of options and redundancy reflects the ability of community to mobilize available resources efficiently. However, various approaches suggest that vulnerability and resilience exist side by side in a system [62]. Although resilience is seen as the opposite of vulnerability [63], they are not necessarily at the opposite ends of the spectrum. They are seen as 'two separate occasionally interconnecting scales showing vulnerability from low to high and resilience high to low' [63], which means that an increase in resilience would decrease vulnerability, whilst a decrease in resilience would increase vulnerability.

According to Turner (2010) [64], vulnerability and resilience are important components of sustainability, with overlapping differences. According to Turner *et al.* (2003) [62] and Gallopin (2006) [65], both resilience and adaptive capacity are parts of vulnerability, whereas Smit *et al.* (1999) [59] consider only adaptive capacity as a component of vulnerability, without any connection between vulnerability, resilience and adaptation. United Nations Disaster Relief Organization (UNDRO) (1980) [66] states that vulnerability and resilience are independent constructs. Chambers and Conway (1992) [67] believe that exposure and vulnerability are within the purview of resilience. Many theorize that resilience is the outcome of vulnerability, or the flip-side of vulnerability, or reciprocal to vulnerability [60]. Although resilience is considered an effect of vulnerability which may be opposite or reciprocal, the absence of vulnerability does not mean resilience of community [60]. Vulnerability cannot be folded into resilience or vice versa [68]. In Herzberg's two-factor theory, absence of

job dissatisfaction does not prove existence of job satisfaction, which means they are not opposite. Similarly, the absence of vulnerability does not prove the presence of resilience measures in a system, as both are discrete entities [68].

For measuring climate vulnerability the research need to focus what has been done so far and what sorts of information available to conduct the research to address the vulnerability, resilience and adaptation framework. The study adopted the method from Aguilar *et al.* (2009) [13]. In their study they have developed a comprehensive method to assess the vulnerability using the vulnerability, resilience and adaptation framework. They developed the integrated climate vulnerability assessment, which was subsequently used to assist the adaptation process, involved the following general steps: (i) characterization of the study area, including the natural and social dynamics and the interaction and coupling between them; (ii) integrated assessment of current climate vulnerability; and (iii) integrated assessment of future climate vulnerability [12]. With appropriate modification research has developed an integrated Climate Vulnerability Index (CVI) equation (Eqn. 4.1), which is functions of 3 dependent sub-indices: Climate Treat Index (CTI) or Exposure, Resilience (R) and Adaptability (A). The mathematical expression of CVI is:

$$CVI = \frac{CTI[2-(R+A)]}{2} \qquad \ldots\ldots (4.1)$$

Where,

CVI is Climate Vulnerability Index

CTI is Climate Threat Index/Exposure

R is Resilience

A is Adaptability

Maximum obtainable value of the CVI is 1 (one) and minimum value of this index is 0 (zero).

This adopted equation (1) is a dynamic equation, where both the weather data and contributing components of study area were duly addressed. The exposure or CTI is assessed from historical and regional climate model data and Adaptability (A) and

Resilience (R) were assessed from contributing factors through an extensive questionnaire. The comprehensive and dynamic characteristics of the formula were the weightage factors to adopt the equation. There are several methodological difference between the Aguilar *et al.* (2009) [13] and this study. In their study, the exposure or CTI assessment was done based on some assumptions, but in this study it was done by using core climate indices for current and future time-slices by analyzing climate data.

4.5.1 Development and Calculation of Climate Threat Index

The major sub-index of the equation of CVI (Eqn. 4.1) is CTI or exposure to changing climate. Measuring the CTI was the real challenge of the research and value is representing the local climate threat. This sub-index is derived from climatic data (historic and modeled) analysis. Construction of this kind of indices or index has taken consideration of its replicability to the other location of the country and also the data availability. These factors have made the concept to use existing approach using in the climate research. Climate scientist community is currently using 27 core indices recommended by Expert Team on Climate Change Detection and Indices (ETCCDI) [37] [38]. The study has been focusing on the first order of climate change impacts and taking the consideration of precipitation and temperature changes only therefore, among these 27 indices 8 indices related to extreme dry or wet events were selected to determine composite indices of climate threat for the study area. These 8 indices were selected for defining the threats in the language of extreme dry or wet events, which are the common determinants of Bangladesh climate extremes [69]. These 8 indices are- Warm Spell Duration Index (WSDI), Percentage of days when TX > 90th percentile (TX90P), Annual total PRCP when RR > 99p (R99p), Maximum length of dry spell, maximum number of consecutive days with RR < 1mm (CDD), Maximum length of wet spell, maximum number of consecutive days with RR ≥ 1mm (CWD), Annual total precipitation in wet days (PRCPTOT), Monthly maximum consecutive 5-day precipitation (Rx5day), and Simple precipitation intensity index (SDII). Baseline CTI (2010) has been calculated from the output of the Rclimdex indices both from observed data and modeled data. Each of the 8 indices have different unit value and to assign in common index should have a common scale of measurement. For converting those into a common scale mathematical standardization have taken place to put those into 0 to 1 scale. The average value of the 1981-2010 for each of the 8 indices were taken

individually and then standardized the values for each indicator separately. The arithmetic average of 8 standardized values of the indices is the present or baseline value for the year of 2010. Accordingly, the future CTIs have been calculated using the same procedure for 2020 (2011-2040), 2050 (2041-2070), and 2080 (2071-2099) using the dynamically downscaled data obtained from regional climate model. Due to availability of bias corrected desired point data only Representative Concentration Pathway (RCP) 8.5 is used here to calculate future climate threat. The mathematical expression of CTI is:

$$CTI = \frac{\sum_{i=1}^{8} S_d indices}{\sum_{i=1}^{8} i} \qquad \text{(4.2)}$$

Where,

$S_d indices$ is the standardize value of the each indices

i is the number of indices

Climate indices for CTI have been computed from the daily observed data of Hatiya station and bias corrected regional model data using specially designed freely available software called Rclimdex. This software was developed by ETCCDMI (Expert Team on Climate Change Detection Monitoring and Indices) and can be downloaded from the ETCCDI website (http://etccdi.pacificclimate.org/software.shtml).

4.5.2 Determination of Climate Resilience and Adaptability

The rest of two sub-indices of the Climate Vulnerability Index are Resilience (R) and Adaptability (A). These two components is primarily derived from community participation by using a close end questionnaire. Resilience and Adaptability are the basic instinct to withstand against climate extremes. Measuring the community resilience and adaptability have made the research more vibrant. Adaptation Policy Framework [12] and more recent concepts of Shared Socio-economic Pathways [42] have given some insights to set variable to measure resilience and adaptability.

4.5.2.1 Variable Identification

The next step of measuring climate resilience and adaptability form the participatory data is variable identification. The variables are identified based on some category which are classified according to the data requirement. This is a complicated process and there is standalone guideline to choose the variables. Based on the research question and the objectives the variables are selected. The whole variable selection process is partially guided by the Adaptation Policy Framework and concept of Shared Socio-economic Pathways.

The variables are classified into three board categories, which are-

1. Socio-cultural Variables (18);
2. Natural Variables (28); and
3. Economic Variables (13).

Under these three broad categories both resilience and adaptability have been holding indicators. Resilience measuring process is distributed among 21 indicators and each of the indicators have a close ended question. Similarly, Adaptability has 38 different indicators reflected over 38 different questions. The variables and the indicators are listed in the following table:

Table 4-3: Resilience and Adaptability measuring variables, indicators, survey questions, and question source.

Major Component	Indicator	Survey Question	Explanation	Source
Resilience				
Socio-cultural Variables	1. Level of public entities and projects within the study area	1. What is the level of Govt. department involvement in your area?	1. No. of public entities and projects within the study area	Adapted from Aguilar *et al.* (2009)
	2. Level of participating non-government entities and projects	2. What is the level of NGO driven activities in your area?	2. No. of participating non-government entities and projects	Adapted from Aguilar *et al.* (2009)
	3. Frequency of locally organized socio-cultural events	3. How often social events take place in your area?	3. Cultural diversification reflect the strong social bonding	Adapted from Aguilar *et al.* (2009)
	4. Contribution of local harmony to cope with natural hazards	4. How your society reacts during disaster?	4. Collective response during disaster indicates better harmony to cope with	Adapted from Aguilar *et al.* (2009)
	5. Level of locally promoted tourism initiatives	5. How often tourist visit your area?	5. Sustainable tourism initiatives reflects the financial sustainability to cope with hazards	Adapted from Aguilar *et al.* (2009)
	6. Effectiveness of local/national cyclone early-warning systems	6. How often you receive cyclone warning?	6. Effectiveness cyclone warning system ensure the better preparedness of local community	Adapted from Aguilar *et al.* (2009)
	7. Delinquency level within the study area	7. How frequently delinquency affect your area?	7. Delinquency is the indicator of social fragility which is harmful for resilience	Adapted from Aguilar *et al.* (2009)
Natural Variables	8. Flood frequency	8. How often flood affect your area?	8. High frequency has higher exposure	Adapted from UNDP (2004), Aguilar *et al.* (2009)
	9. Soil permeability and drainage capacity	9. How quick flood water drain out?	9. Longer flooding period has higher loss	Adapted from UNDP (2004), Aguilar *et al.* (2009)
	10. Soil salinity	10. How much the soil salinity is?	10. High salinity has negative impact on agricultural production	Adapted from UNDP (2004), Aguilar *et al.* (2009)
	11. Availability of, and access to, underground water	11. How often you use ground/tube well water?	11. Indicates the access to the safe drinking water	Adapted from World Bank (1997)
	12. Conflict between potential and actual land use	12. How often you cultivates your land during a year?	12. Marginal land use have higher agricultural risk	Adapted from Aguilar *et al.* (2009)

Major Component	Indicator	Survey Question	Explanation	Source
	13. Level of deforestation	13. How quick the forest/mangrove degrading?	13. Higher rate of deforestation have greater threat to hazard exposure	Adapted from UNDP (2004), Aguilar *et al.* (2009)
	14. Soil pollution due to fertilizers, pesticides and waste	14. How widely people using chemical fertilizer and pesticides?	14. Higher use of chemical fertilizer poses threat of chemical pollution	Adapted from World Bank (1997)
	15. Level of exploitation of local land, aquatic and marine species	15. What percentage/portion of people involve in fishing?	15. Higher fishing folks indicates the less livelihood diversity	Adapted from Aguilar *et al.* (2009)
	16. Contribution of protection works to flood mitigation	16. How the coastal embankment protects from flood?	16. Sound coastal embankment is first order protection measure against surge/flood	Adapted from Aguilar *et al.* (2009)
	17. Protection of the existing natural areas	17. How the activities are protecting natural resources?	17. Natural resource conservation indicates the sustainable natural resources development	Adapted from Aguilar *et al.* (2009)
Economic Variables	18. Level of local agricultural activities	18. How common the agriculture is?	18. The livelihood activities in addition to other activities reported by households	Adapted from DHS (2006); Hahn *et al.* (2009)
	19. Percent income from activities other than agriculture or livestock	19. How much you earned from activities other than agriculture?	19. Percentage of households that reported only agriculture as their source of income	Adapted from World Bank (1998); Hahn *et al.* (2009)
	20. Relative efficiency in the agriculture or livestock productive activities	20. How easy to practice agriculture?	20. Easier agricultural activity lower the production cost	Adapted from Aguilar *et al.* (2009)
	21. Technological response in the agriculture/livestock sector	21. How beneficial the tractor or other agricultural equipment?	21. Modern technology use have higher agricultural production	Adapted from Aguilar *et al.* (2009), World Bank (1997)
Adaptive Capacity				
Socio-cultural Variables	1. Levels of local development work	1. How development works have implemented last 10 years?	1. Effective local development reduce the climate risk	Adapted from Aguilar *et al.* (2009), World Bank (1997)
	2. Level of climate resilient local development work	2. How the development works have contributed to cope with hazard/climate risk?	2. Effective local development reduce the climate risk and better hazard preparedness	Adapted from Aguilar *et al.* (2009)
	3. Level of foreign aided development projects	3. How foreign aid available for local development?	3. Donor contribution to the local development as well as climate response	Adapted from Aguilar *et al.* (2009)

Major Component	Indicator	Survey Question	Explanation	Source
	4. Contribution of local activities to conservation of the environment	4. How the local activities impacted environmental conservation?	4. Contribution of local activities to conservation of the environment	Adapted from Aguilar *et al.* (2009)
	5. Income level of the local population	5. What is the income level of local people?	5. Higher level of income have higher adaptive capacity against climate change	Adapted from Aguilar *et al.* (2009), World Bank (1997)
	6. Level of access to basic services	6. How often the basic services available?	6. Reflects the availability of basic facilities	Adapted from World Bank (1997)
	7. Level of access to natural resources for local food security	7. How natural resources contributed to the food security?	7. Food dependency on natural sources reflects less resiliency	Adapted from World Bank (1997)
	8. Level of access to credit, technical assistance and training	8. How often people can get micro-credit?	8. Access to micro-credit indicates financial accessibility	Adapted from World Bank (1997)
	9. Level of access to transport	9. How available the public transport is?	9. Better transportation can ensure better mobility during hazard or improve economic activity	Adapted from Aguilar *et al.* (2009), World Bank (1997)
	10. Level of access to communications	10. How improve the communication system?	10. Better communication indicate the improve infrastructural development	Adapted from Aguilar *et al.* (2009), World Bank (1997)
	11. Level of access to cyclone shelter	11. How many cyclone shelter located in your area?	11. Adequate number of cyclone shelter can provide shelter to the community during disaster	Adopted from CEGIS (2009)
Natural Variables	12. Soil sedimentation and erosion	12. How the sedimentation and erosion regulate the land?	12. High erosion and siltation rate is major threat to local community	Adapted from UNDP (2004), Aguilar *et al.* (2009)
	13. Rivers and creeks that have changed their course	13. How often the channels/creeks changed their course for sedimentation/erosion?	13. Frequent change in water course can make the community more vulnerable	Adapted from UNDP (2004), Aguilar *et al.* (2009)
	14. Susceptibility to cyclone and tidal surge	14. How often cyclone hit your area?	14. Higher the cyclone landing rate have higher vulnerability and lower adaptive capacity	Adapted from UNDP (2004), Aguilar *et al.* (2009)
	15. Flow of river water in local streams	15. How tidal water affect your area?	15. Tidal intrusion exacerbated the salinity	Adapted from UNDP (2004), Aguilar *et al.* (2009)

Major Component	Indicator	Survey Question	Explanation	Source
	16. Seasonal moisture content of soil	16. How long surface retain rain water?	16. More surface water retention have prolonged fresh water availability period	Adapted from UNDP (2004), Aguilar *et al.* (2009)
	17. Soil agrological potential	17. How fertile your soil?	17. Soil fertility is the indication of higher productivity	Adapted from UNDP (2004), Aguilar *et al.* (2009)
	18. Number of different ecosystems	18. How many type of ecosystem do you see?	18. Diversified ecosystem can supply diverse resources	Adapted from UNDP (2004), Aguilar *et al.* (2009)
	19. Relative amount of plant and animal species	19. How many type of plant and animal species available in your area?	19. Diversified ecosystem can supply diverse resources	Adapted from UNDP (2004), Aguilar *et al.* (2009)
	20. Habitat loss threat	20. What is the rate of change of forest area?	20. Higher the forest degradation rate increase the physical and ecological threat	Adapted from UNDP (2004), Aguilar *et al.* (2009)
	21. Proportion of land consisting of environmental corridors and natural areas	21. What percentage/portion of land under forest/mangrove coverage?	21. More forest coverage can ensure better protection	Adapted from UNDP (2004), Aguilar *et al.* (2009)
	22. Availability of plants and forest products for human and livestock food, and for sale	22. How forest and rivers/channels help to collect basic amenities?	22. Forest and channels are the sources of natural resources	Adapted from UNDP (2004), Aguilar *et al.* (2009)
	23. Availability of energy-related forest species for family use, production and sale	23. How much fuel wood you collect from forest?	23. Higher the forest dependency increase the forest degradation rate	Adapted from UNDP (2004), Aguilar *et al.* (2009)
	24. Availability of aquatic and marine species for human consumption and fishing	24. How the river and estuary provide aquatic and marine resources?	24. River and estuaries are the major aquatic resources sources	Adapted from UNDP (2004), Aguilar *et al.* (2009)
	25. Level of scenic beauty for human welfare and tourism	25. How beautiful the forest and rivers are?	25. Beautiful forest and rivers can attract tourist from outside	Adapted from UNDP (2004), Aguilar *et al.* (2009)
	26. Availability of forest species for consumption and sale	26. How available the forest resources are?	26. Forest is the major source of natural resources	Adapted from UNDP (2004), Aguilar *et al.* (2009)
	27. Availability of water for family use	27. How available household safe water?	27. Access to the safe drinking water can ensure the good health	Adapted from UNDP (2004), Aguilar *et al.* (2009)

Major Component	Indicator	Survey Question	Explanation	Source
	28. Availability of water for local productive activities	28. How available the water for agriculture?	28. Availability of agricultural water could have positive impact on food production	Adapted from UNDP (2004), Aguilar *et al.* (2009)
	29. Forest contribution to cyclone mitigation	29. How the forest do protects from cyclone?	29. Contribution of coastal green belt to protect from cyclone	Adapted from UNDP (2004), Aguilar *et al.* (2009)
Economic Variables	30. Basic grain planted area	30. What is the coverage of agriculture/crop land?	30. More agricultural land indicates better food production	Adapted from World Bank (1997)
	31. Diversity of livelihoods associated with local survival strategies	31. What is the diversity of livelihoods activities in your area?	31. The livelihood activities in addition to other activities reported by households	Adapted from DHS (2006); Hahn et al. (2009)
	32. Percent people with access to technical assistance for production	32. What percent or portion of people can use tractor or irrigation pump?	32. Use of modern agricultural technology can increase food production	Adapted from Aguilar *et al.* (2009), World Bank (1997)
	33. Percent producers with innovative methods and technology	33. What percentage or portion of people use modern agriculture technology?	33. Use of modern agricultural technology can increase food production	Adapted from Aguilar *et al.* (2009), World Bank (1997)
	34. Percent producers using irrigation in productive activities	34. What percent or portion of people using irrigation scheme?	34. Indicates less dependency on natural sources and have access to the irrigation scheme	Adapted from World Bank (1997)
	35. Percent people who own the land for the agriculture or livestock	35. What percent/portion of people have their own agricultural land?	35. Farmland ownership indicates household food security	Adapted from World Bank (1997)
	36. Percent people who have access to credit for economic activities	36. What percent/portion of people have taken credit from micro credit organization?	36. Access to micro-credit indicates financial accessibility	Adapted from World Bank (1997)
	37. Access to local human settlements and land plots	37. What percent/portion of people have their own homestead?	37. Indicates the poverty level of the study area	Adapted from World Bank (1997)
	38. Level of markets available and accessible for what is locally produced Percent of market-oriented production	38. How often people can go to the market?	38. Access to the market indicates frequent economic activity	Adapted from Aguilar *et al.* (2009)

4.5.2.2 Questionnaire Design

Instead of using other participatory techniques, the questionnaire survey has been picked for the complex nature of the research and the research required quantitative data to figure out the sub-indices. Therefore, the variables have been identified to translate the variable into related questions into comprehensive questionnaire for field data collection. Initially a draft structure has been designed in bi-lingual (both Bengali and English) questions with some respondent line items. The questionnaire has incorporated the date of data collection, respondent name, age, gender, occupation, village, Union Parishad, Upazila, District, respondent contact number, and lastly the location of data collection point. These parameters have been introduced for respondent authentication and verification. Except the personal line items the core 59 questions are close ended. Each question had five level of responding point (very bad, bad, neutral, good, and very good). All the 59 questions must be answered by the respondent. Each of the question is equal weightage and enumerators are instructed to put a tick mark over any of the five level of responding points after getting the respondent answer with proper explanation of the each questions.

4.5.2.3 Field Testing

A field test has been performed at the study site. After having the field test result the questionnaire had been modified. Initially the questionnaire was left blank in the five level of the responding points. Due to complex nature of the questions enumerators were facing difficulties in explain the question to the respondents, but their clear understanding was pre-requisite. In the modified version of the questionnaire probable answers have been incorporated in each of the responding points. Therefore, the questionnaire incorporated with 295 (59x5) probable answers. Now the questionnaire become easier than the earlier version.

4.5.2.4 Sampling Method

Multistage sampling method [70] [71] is used in this study. In multistage sampling the population is regarded as being composed of a number of first stage or primary sampling units (PSU's) each of them being made up of a number of second stage units in each selected PSU and so the procedure continues down to the final sampling unit, with the sampling ideally being random at each stage [72]. Under this process the whole

study area was initially clustered based on their geographic location and historical climate event response. It is more cost-effective to select respondents in groups ('clusters'). The sampling method was chosen intentionally for the nature of the study. The objective of the research is to assess the vulnerability of different community or location within a wider geography. In this study in the first stage of the sampling the 10 clusters were chosen based on vulnerability due to their geographic location. As the study area Hatiya is a remote coastal island situated at Meghna estuary. The peripheral parts and southern Nijhum Dwip is highly exposed to climate extremes. Therefore, the primary clusters were chosen at the periphery and southern Nijhum Dwip. In the second stage, 10 samples were taken randomly to bring the questionnaire information for assessing resilience and adaptability. This sampling method reduce the time and resource limitations and also complemented to the research objective to identify the location specific vulnerability. Hence, a 'Multi-stage random sampling' was done in the study. In the recent time, larger studies on natural resources or climate change are using this method to increase the cost-effectiveness and also the data representativeness.

A Climate-Based Model Predicts [73] research in United States used the multistage sampling method to reduce the time and for increasing the representativeness of certain forest species. Where, sampling designed a multistage sampling scheme. The first stage were involved stratified random sampling, where a specified number of cells were selected for sampling with equal allocation to probability groups divided by quintiles. The second sampling stage involved sampling specified species within each cell selected in the first stage. To standardize the sampling effort, a state park or state forest was selected at each sample grid cell. As a result, the study got similar deciduous forest habitat at each site.

4.5.2.5 Sample Size

No core established sample size determination formula was followed in the study. The length and complexity of the questionnaire format, required time, capacity of surveyor and weather condition collectively backfired during the survey. Available resource became another constrain for data collection.

Finally, the study clustered the study area in 10 clusters based on their geographic location and historical climate event response. This clustering was done intentionally to determine the different location specific climate vulnerability index (CVI). Over the 10 clusters 100 equally distributed (10 for each location) samples were taken randomly. Behind the identification of the number 100 there was no statistical method. Only the research need and the nature and complexity of the study worked as determinant to pick the number. The 10 clusters were identified on the basis of Google Maps and secondary data representation the socio-economic condition of the local community. In the second stage of the sampling from each of the clusters 10 random samples were taken for questionnaire survey. During the random sampling two parameters were in consideration. These parameters are-

1. Age of the sample; and
2. Gender of the sample.

As the study is centering on climate evidence, therefore the age was chosen as important factor for respondent. Higher the age of respondent/sample higher the historical evidence/reference. Gender is the critical factor for climate study, which is certain gender group is more sensitive to climate event than other.

4.5.2.6 Data Collection and Data Analysis

Depending on the questionnaire size it was assumed that the data collection will take longer time in self data collection. Under this consideration enumerators were fielded for data collection. Before, grounding them in the field an orientation were organized. In this study 3 enumerators were involved in field data collection for more than one month (including interval). The data were collected in individual basis (one to one) at their (sample) native location. Each question was properly interpreted by the enumerator to the respondent and in return respondent placed his opinion against the five (very bad, bad, neutral, good, and very good) given category to put a tick mark by the enumerator.

After the completion of the data collection, filled up questionnaires were received at Dhaka for further process. For data entry, a Google Form interface was used for entering the values of 100 questionnaire. The questionnaires were assigned by geographic

cluster for analysis. Each geographic cluster received 10 questionnaires for analysis. The very bad, bad, neutral, good, and very good responses were replaced by 0, 0.25, 0.50, 0.75, and 1 for numerical analysis.

First, 21 questions of the questionnaire were assigned for measuring baseline (2010) Resilience (R) of the respective location. The arithmetic mean of the total 21 questions were taken for each sample, and the mean of the 10 samples were taken as cluster's resilience for the baseline period. Similarly later, 38 questions of the questionnaire were taken for Adaptability (A) calculation for baseline period. Mean of the 38 questions assigned for individual response and mean of 10 samples collectively reflected geographic cluster's adaptability.

4.5.2.7 Future Projection of Climate Resilience and Adaptability

Projection of climate resilience and adaptability were posed enormous challenge to this study. Currently climate scientist communities are trying to establish the statistical or mathematical relation between economic growth and climate change impacts (adaptability and resilience). By reviewing the literature it has been cleared that there is an unambiguous and positive link between economic growth and adaptive capacity [74]. At present, there is no quantified expression to calculate the future resilience and adaptability. Based on Shared Socio-economic Pathways (SSP) few researches have been done to forecast economic growth and population relating GDP [75]. International Institute for Applied Systems Analysis (IIASA), an international scientific institute that conducts policy-oriented research into problems that are too large or too complex to be solved by a single country or academic discipline. This international institute has developed a database for research community on SSP scenarios. Country wise projected economic growth rate data [76] have been given in the online data base. Bangladesh economic growth rate data have retrieve from the database and the SSP3 scenario data of IIASA have been used for this study. SSP3 scenario where Unmitigated emissions are high due to moderate economic growth, a rapidly growing population, and slow technological change in the energy sector, making mitigation difficult. Investments in human capital are low, inequality is high, a regionalized world leads to reduced trade flows, and institutional development is unfavorable, leaving large numbers of people vulnerable to climate change and many parts of the world with low adaptive capacity

[42] is suitable scenario for Bangladesh. Under this scenario Resilience (R) and Adaptability (A) have been calculated using the following two equations-

For Resilience (R)

$$R_t = R_b + \left[\frac{G_t}{(R_b)^{\left((1/t-1)-1\right)}}\right]^{-\left((1/t-1)-1\right)} \quad \text{..... (4.3)}$$

Where,

R_t is projected resilience (R) at year of t

R_b is base resilience for given period

G_t is GDP growth rate for the t time period

t is difference between projected and base year

Similarly, for Adaptability (A)

$$A_t = A_b + \left[\frac{G_t}{(A_b)^{\left((1/t-1)-1\right)}}\right]^{-\left((1/t-1)-1\right)} \quad \text{..... (4.4)}$$

Where,

A_t is projected adaptability (A) at year of t

A_b is base adaptability for given period

G_t is GDP growth rate for the t time period

t is difference between projected and base year

These two equations are derived from the Compound Annual Growth Rate (CAGR) [77] calculation equation. As there is positive relation between economic growth and climate adaptive capacity, therefore, these equations appeared like in this way.

In the above two formula the growth rate (G_t) used is the mean of the subsequent three decadal values of SSP3 IIASA scenario provided in the SSP Database (Version 1.0). Base resilience and adaptability is the earlier time period value. For example in the

calculation of 2020 values the base value is used in 2010. Similarly, for 2050 and 2080 the based values were 2020 and 2050 respectively.

4.5.3 Composite Climate Vulnerability Index Calculation

The final outcome of the climate vulnerability index (CVI) is the composite value derived from the equation (Eqn. 4.1). For the base period CTI value was taken from both observed and model data of 2010 and for subsequent time-slices. CTI values were taken from model data and the CTI values were calculated by using equation (Eqn. 4.2). In the base year calculation of CVI, the values of R and A were derived from the field data. On the other hand, for subsequent time-slices R and A values were taken from the outputs of equation (Eqn. 4.3) and (Eqn. 4.4).

4.5.4 Vulnerability Mapping

For better understanding, the results have been mapped using GIS. The vulnerability maps are prepared using ArcGis 10.3. For administrative boundary LGED data base has been used and for base map Esri, HERE, DeLorme, MappyIndia GIS data based has been used to develop the maps.

CHAPTER 5 : CLIMATE VULNERABILITY INDEX ASSESSMENT

5.1 Introduction

The study followed a holistic move combining both quantitative (statistical analysis) and participatory approach to measure or assess Climate Vulnerability Index. This chapter has describes the results calculated from different comprehensive processes. This chapter is the core part, where whole processes outcomes have been reflected in narratives or in graphics (chart and maps).

5.2 Integrated Assessment of Baseline Climate Vulnerability

Climate Vulnerability Index (CVI) is a comprehensive process. To assess the CVI needs to comply several independent process. CVI has tree independent sub-indices namely- resilience, adaptability and exposure or climate threat index. Step wise process have been described in the following sections.

5.2.1 Baseline Resilience

Due to observed weather data availability limitations the baseline period has been fixed year of 2010. Although, the filed data has been collected on 2015, the study hereinafter has been referred baseline to 2010. Questionnaire survey has been done to assess the current resilience and adaptability of the study area. The questionnaire was incorporated with 59 questions (21 for resilience and 38 for adaptability) were individually interviewed to assess the variables with a five level (very bad = 0, bad = 0.25, neutral = 0.50, good = 0.75, and very good = 1.0) respondent end. During the participatory survey enumerator's responsibility was to explain the each question to get the reflection (based on his experience) from local context. Total 100 (80 male and 20 female) questionnaires were surveyed in ten different locations. Among the respondent female respondent average age was 41 and male respondent average age was 44 years. For each location ten respondents were interviewed and after having their response average values of the each questions were taken as baseline response. First, 21 questions collectively referred as baseline (2010) resilience of that particular location.

Table 5-1: Question Wise Resilience (R) Calculation Process from Questionnaire Data

Sl	Question	Nijhum Dwip	Moktaria	Jahajmara	Sonadia	Burirchar	Tomoroddi	Char Ishwar	Nolchira	Harni	Hatiya Paurashava
1.	What is the level of Govt. department involvement in your area?	0.43	0.30	0.25	0.85	0.50	0.60	0.33	0.30	0.38	0.70
2.	What is the level of NGO driven activities in your area?	0.93	0.58	0.75	0.78	0.58	0.65	0.68	0.58	0.60	0.75
3.	How often social events take place in your area?	0.25	0.23	0.63	0.68	0.38	0.75	0.85	0.18	0.40	0.65
4.	How your society reacts during disaster?	0.80	0.63	0.50	0.73	0.53	0.75	0.55	0.65	0.65	0.60
5.	How often tourist visit your area?	0.83	0.28	0.48	0.28	0.08	0.00	0.63	0.00	0.08	0.05
6.	How often you receive cyclone warning?	0.65	0.75	0.40	0.58	0.55	0.55	0.53	0.75	0.70	0.65
7.	How frequently delinquency affect your area?	0.63	0.45	0.55	0.70	0.55	0.78	0.55	0.60	0.75	0.75
8.	How often flood affect your area?	0.08	0.10	0.00	0.15	0.18	0.20	0.05	0.15	0.13	0.20
9.	How quick flood water drain out?	0.75	0.75	0.38	0.38	0.43	0.33	0.33	0.73	0.73	0.43
10.	How much the soil salinity is?	0.33	0.38	0.50	0.60	0.65	0.55	0.50	0.50	0.50	0.73
11.	How often you use ground/tube well water?	0.50	0.45	0.45	0.30	0.00	0.23	0.50	0.45	0.20	0.13
12.	How often you cultivates your land during a year?	0.48	0.48	0.40	0.73	0.70	0.78	0.60	0.50	0.58	0.75
13.	How quick the forest/mangrove degrading?	0.35	0.38	0.23	0.75	0.63	0.78	0.33	0.80	0.90	0.83

Sl	Question	Nijhum Dwip	Moktaria	Jahajmara	Sonadia	Burirchar	Tomoroddi	Char Ishwar	Nolchira	Harni	Hatiya Paurashava
14.	How widely people using chemical fertilizer and pesticides?	0.38	0.40	0.30	0.63	0.58	0.73	0.25	0.33	0.58	0.55
15.	What percentage/portion of people involve in fishing?	0.15	0.15	0.30	0.50	0.63	0.75	0.28	0.20	0.15	0.78
16.	How the coastal embankment protects from flood?	0.00	0.60	0.50	0.53	0.70	0.60	0.48	0.08	0.28	0.68
17.	How the activities are protecting natural resources?	0.60	0.53	0.53	0.60	0.45	0.65	0.40	0.23	0.58	0.48
18.	How common the agriculture is?	0.48	0.43	0.53	0.80	0.65	0.83	0.65	0.35	0.40	0.75
19.	How much you earned from activities other than agriculture?	0.85	0.73	0.63	0.50	0.33	0.70	0.65	0.95	0.68	0.43
20.	How much easy to practice agriculture?	0.50	0.68	0.53	0.85	0.83	0.85	0.65	0.58	0.63	0.93
21.	How beneficial the tractor or other agricultural equipment?	0.33	0.55	0.55	0.73	0.70	0.75	0.65	0.28	0.45	0.78
	Resilience (R)	**0.49**	**0.47**	**0.45**	**0.60**	**0.50**	**0.61**	**0.50**	**0.44**	**0.49**	**0.60**

Table 5-2 is showing the result of the resilience different locations of the Hatiya Upazila. The resilience varies for their geographic location, socio-economic activity, natural environment, and natural resource dependency. Institutional effectiveness has significant impact on resilience. The resilience is reflected here 0 to 1 scale, where the minimum value is 0.44 for Nalchira which most vulnerable location to extensive erosion and maximum value is 0.61 of Tomoroddi a strategic location for economic activity.

Table 5-2: Baseline Resilience of Different Locations of Hatiya Upazila

Sl	Location	Resilience (R)
1	Nijhum Dwip	0.49
2	Moktaria	0.47
3	Jahajmara	0.45
4	Sonadia	0.60
5	Burirchar	0.50
6	Tomoroddi	0.61
7	Char Ishwar	0.50
8	Nolchira	0.44
9	Harni	0.49
10	Hatiya Paurashava	0.60

5.2.2 Baseline Adaptability

Similarly, Table 5-3 is the detail question wise field response calculation process and Table 5-4 is showing the results of adaptability of different surveyed location of the Hatiya Upazila. Adaptability is the outcome of the 38 individual question of the questionnaire. These 38 questions are grouped into three broad category namely- socio-cultural, natural and economic variables. Adaptive capacity or adaptability is different from the resilience and there is no direct correlation between them. The adaptability is highest in Sonadia which is 0.54 and lowest in Nalchira and Harni (0.40), where geomorphological and environmental changes are very frequent. Survey results are also showing the unstable natural variables posing threats to these two locations. Local variable changes with external factors limiting the adaptability of these leased ranked locations.

Table 5-3: Question Wise Adaptability (A) Calculation Process from Questionnaire Data

Sl	Question	Nijhum Dwip	Moktaria	Jahajmara	Sonadia	Burirchar	Tomoroddi	Char Ishwar	Nolchira	Harni	Hatiya Paurashava
1.	How development works have implemented last 10 years?	0.30	0.45	0.25	0.63	0.30	0.50	0.30	0.45	0.40	0.58
2.	How the development works have contributed to cope with hazard/climate risk?	0.38	0.55	0.35	0.65	0.28	0.55	0.33	0.58	0.30	0.40
3.	How foreign aid available for local development?	0.63	0.40	0.40	0.53	0.33	0.48	0.33	0.40	0.35	0.48
4.	How the local activities impacted environmental conservation?	0.78	0.63	0.33	0.60	0.38	0.73	0.35	0.60	0.58	0.58
5.	What is the income level of local people?	0.30	0.30	0.53	0.70	0.60	0.73	0.73	0.18	0.38	0.53
6.	How often the basic services available?	0.20	0.35	0.28	0.48	0.30	0.35	0.45	0.18	0.30	0.38
7.	How natural resources contributed to the food security?	0.40	0.38	0.48	0.73	0.43	0.55	0.55	0.40	0.40	0.40
8.	How often people can get micro-credit?	0.55	0.50	0.68	0.68	0.53	0.55	0.68	0.60	0.48	0.55
9.	How available the public transport is?	0.23	0.13	0.30	0.45	0.25	0.35	0.33	0.15	0.13	0.35
10.	How improve the communication system?	0.30	0.30	0.33	0.60	0.40	0.63	0.50	0.23	0.25	0.55
11.	How much cyclone shelter in your area?	0.23	0.28	0.35	0.43	0.30	0.33	0.28	0.25	0.23	0.43
12.	How the sedimentation and erosion regulate the land?	0.50	0.33	0.35	0.68	0.78	0.58	0.33	0.20	0.30	0.65

Sl	Question	Nijhum Dwip	Moktaria	Jahajmara	Sonadia	Burirchar	Tomoroddi	Char Ishwar	Nolchira	Harni	Hatiya Paurashava
13.	How often the channels/creeks changed its course for sedimentation/erosion?	0.43	0.43	0.48	0.48	0.38	0.50	0.38	0.35	0.35	0.43
14.	How often cyclone hit your area?	0.08	0.08	0.10	0.15	0.13	0.30	0.00	0.03	0.10	0.18
15.	How tidal water affect your area?	0.43	0.43	0.48	0.53	0.50	0.48	0.43	0.45	0.35	0.50
16.	How long surface retain rain water?	0.50	0.43	0.55	0.60	0.70	0.38	0.45	0.45	0.45	0.70
17.	How fertile your soil?	0.65	0.48	0.55	0.60	0.65	0.55	0.45	0.48	0.50	0.63
18.	How many type of ecosystem do you see?	0.73	0.65	0.53	0.40	0.45	0.38	0.43	0.20	0.40	0.45
19.	How many type of plant and animal species available in your area?	0.38	0.48	0.28	0.58	0.63	0.85	0.25	0.28	0.50	0.63
20.	What is the rate of change of forest area?	0.50	0.53	0.38	0.73	0.48	0.98	0.25	0.83	0.68	0.75
21.	What percentage/portion of land under forest/mangrove coverage?	0.53	0.80	0.70	0.45	0.58	0.28	0.70	0.00	0.25	0.55
22.	How forest and rivers/channels help to collect basic amenities?	0.48	0.45	0.23	0.58	0.53	0.70	0.18	0.58	0.45	0.65
23.	How much fuel wood you collect from forest?	0.33	0.33	0.25	0.65	0.45	0.70	0.18	0.63	0.70	0.55
24.	How the river and estuary provide aquatic and marine resources?	0.85	0.98	0.53	0.18	0.10	0.13	0.55	0.88	0.50	0.20
25.	How beautiful the forest and rivers are?	0.55	0.35	0.48	0.35	0.20	0.45	0.70	0.08	0.13	0.20
26.	How available the forest resources are?	0.63	0.78	0.48	0.33	0.25	0.25	0.53	0.00	0.10	0.10
27.	How available household safe water?	0.63	0.58	0.43	0.55	0.53	0.58	0.68	0.60	0.53	0.55

Sl	Question	Nijhum Dwip	Moktaria	Jahajmara	Sonadia	Burirchar	Tomoroddi	Char Ishwar	Nolchira	Harni	Hatiya Paurashava
28.	How available the water for agriculture?	0.05	0.00	0.20	0.35	0.08	0.43	0.00	0.00	0.05	0.00
29.	How the forest do protects from cyclone?	0.80	0.85	0.53	0.38	0.48	0.28	0.73	0.78	0.15	0.45
30.	What is the land coverage of agriculture/crop?	0.30	0.45	0.48	0.58	0.63	0.58	0.65	0.25	0.30	0.55
31.	What is the diversity of livelihoods activities in your area?	0.18	0.48	0.60	0.63	0.33	0.58	0.53	0.35	0.33	0.40
32.	What percent or portion of people can use tractor or irrigation pump?	0.40	0.65	0.53	0.68	0.45	0.68	0.60	0.45	0.73	0.65
33.	What percentage or portion of people use modern agriculture technology?	0.23	0.38	0.43	0.68	0.38	0.58	0.43	0.23	0.55	0.65
34.	What percent or portion of people using irrigation scheme?	0.20	0.25	0.25	0.25	0.15	0.28	0.25	0.25	0.25	0.25
35.	What percent/portion of people have their own agricultural land?	0.33	0.78	0.63	0.65	0.75	0.60	0.73	0.73	0.70	0.73
36.	What percent/portion of people have taken credit from micro credit organization?	0.50	0.60	0.58	0.50	0.48	0.40	0.68	0.63	0.55	0.53
37.	What percent/portion of people have their own homestead?	0.35	0.73	0.70	0.88	0.73	0.80	0.73	0.75	0.70	0.78
38.	How often people can go to the market?	0.85	0.60	0.28	0.85	0.73	0.80	0.55	0.80	0.73	0.90
	Adaptability (A)	**0.44**	**0.48**	**0.43**	**0.54**	**0.43**	**0.52**	**0.45**	**0.40**	**0.40**	**0.49**

Table 5-4: Baseline Adaptability of Different Locations of Hatiya Upazila

Sl	Location	Adaptability (A)
1	Nijhum Dwip	0.44
2	Moktaria	0.48
3	Jahajmara	0.43
4	Sonadia	0.54
5	Burirchar	0.43
6	Tomoroddi	0.52
7	Char Ishwar	0.45
8	Nolchira	0.40
9	Harni	0.40
10	Hatiya Paurashava	0.49

5.2.3 Baseline Climate Threats Index

In this study climate threat is referred as Climate Threat Index (CTI) hereinafter. CTI is a composite index derived from eight individual core indices of ETCCDI suggested 27 indices. These eight core indices were selected for Bangladesh perspective and also considering the data availability. These indices are generally denotes the wet and dry climate events. The observed value of CTI is generated from the Hatiya Station of Bangladesh Meteorological Department (BMD) provided 1966 to 2010 Tmax, Tmin and Precepitation.

In the Table 5-5 the baseline CTI results are showing. From the Table 5.5 it has been showing the variation of the result of baseline (2010) CTI between observed and model data. CTI derived from observed data (0.32) is little bit higher than the model data (0.29). This could be due the robust distributed nature of the model data. As the observed data are extreme in nature and do not follow particular trend line, therefore the observed data result is different from the model data. From the climate/global perspective the scale of area or expansion (north to south 50 km, and east to west 20 km) of the study area (Hatiya) is very small and within the study area it has been assumed that there is no variation in climate variables. Therefore, the CTI value of whole study area is considered same for a specified period of time, which is the values changes with time not within the geography.

Table 5-5: Baseline Climate Threat Index Derived from Observed and Model Data

Sl	Index	CTI (2010) Observed	CTI (2010) Model
1	WSDI	0.15	0.02
2	TX90P	0.30	0.10
3	R99p	0.20	0.24
4	CDD	0.23	0.26
5	CWD	0.31	0.47
6	PRCPTOT	0.63	0.51
7	RX5day	0.31	0.20
8	SDII	0.43	0.48
CTI		**0.32**	**0.29**

5.2.4 Baseline Climate Vulnerability Index

Baseline (2010) Climate Vulnerability Index (CVI) is reflecting the vulnerability of present time. Baseline CVI has been calculated using the Equation 4.1. As there were two (observed and model) sets of climatic data for baseline period, therefore the baseline CVI has two different values. One value is derived from observed baseline CTI and the other is from model baseline CTI. These two different values are almost similar with some minor difference. Table 5-6 is depicted the variation of CVI among different locations of Hatiya Upazila. From the tabulated values it has been observed that the northern and southern extremes of Hatiya Upazila is more vulnerable to climate change. Mid-western parts have lower CVI values, which means these locations have higher resilience and adaptive capacity against climate extremes.

Table 5-6: Baseline (observed & model) Climate Vulnerability Index of ten locations

Sl	Area	CVI (2010) Observed	CVI (2010) Model
1	Nijhum Dwip	0.17	0.16
2	Moktaria	0.17	0.15
3	Jahajmara	0.18	0.16
4	Sonadia	0.14	0.12
5	Burirchar	0.17	0.15
6	Tomoroddi	0.14	0.13
7	Char Ishwar	0.17	0.15
8	Nolchira	0.19	0.17
9	Harni	0.18	0.16
10	Hatiya Paurashava	0.15	0.13

5.3 Integrated Assessment of Future Climate Vulnerability

Assessment of future climate vulnerability is an integrated process. Before assessing the future values the study went through the three prior steps, which are future assessment/measuring of resilience, adaptability, and climate threat index. Steps wise processes have been elaborated in the following sections.

5.3.1 Future Resilience

So far the researches have covered the measuring of resilience of present situation. Assessment of future resilience brought new challenge to this study. From economic perspective and recent invention through SSPs an empirical formula (Eqn 4.3) has been proposed in section 4.5.2.7 of this report to assess future resilience. The formula has two independent variables which are GDP growth rate (Table 5-7) and baseline resilience. Based on the Eqn. 4.3 the results have been projected in Table 5-8 for three (2020, 2050, and 2080) time-slices. The results showing steady incremental trends in resilience of different locations of Hatiya Upazila.

Table 5-7: IIASA GDP Model Projected Growth Rate for SSP3 Scenario

Model	Scenario	Unit	2010	2020	2030	2040	2050	2060	2070	2080	2090
IIASA GDP	SSP3	Annual Average Growth [%]	3.966	2.159	1.358	1.166	0.942	0.866	0.897	0.903	0.939
Average for Time Slots				1.561			0.902			0.921	

Table 5-8: Baseline and Future Resilience of Different Locations of Hatiya Upazila

Sl	Area	R (2010)	R (2020)	R (2050)	R (2080)
1	Nijhum Dwip	0.49	0.50	0.51	0.51
2	Moktaria	0.47	0.48	0.48	0.49
3	Jahajmara	0.45	0.46	0.46	0.47
4	Sonadia	0.60	0.62	0.62	0.63
5	Burirchar	0.50	0.52	0.52	0.53
6	Tomoroddi	0.61	0.63	0.63	0.64
7	Char Ishwar	0.50	0.51	0.52	0.52
8	Nolchira	0.44	0.45	0.45	0.46
9	Harni	0.49	0.50	0.51	0.52
10	Hatiya Paurashava	0.60	0.61	0.62	0.63

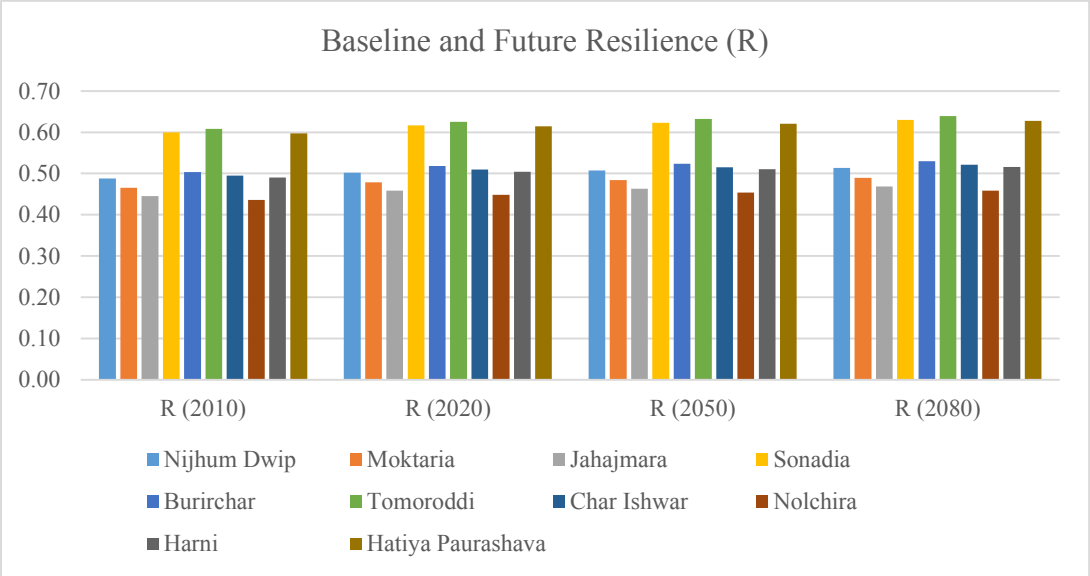

Figure 5.1: Baseline and Future Resilience of Different Locations of Hatiya Upazila

Figure 5.1 is clearly delineating the resilience cluster values. The middle-western three locations (Paurashava, Sonadia, and Tomoroddi) have higher resilience values than other locations. These locations have better coping capacity against the climatic shocks. Other seven locations resilience value is clustering between 0.4 and 0.5.

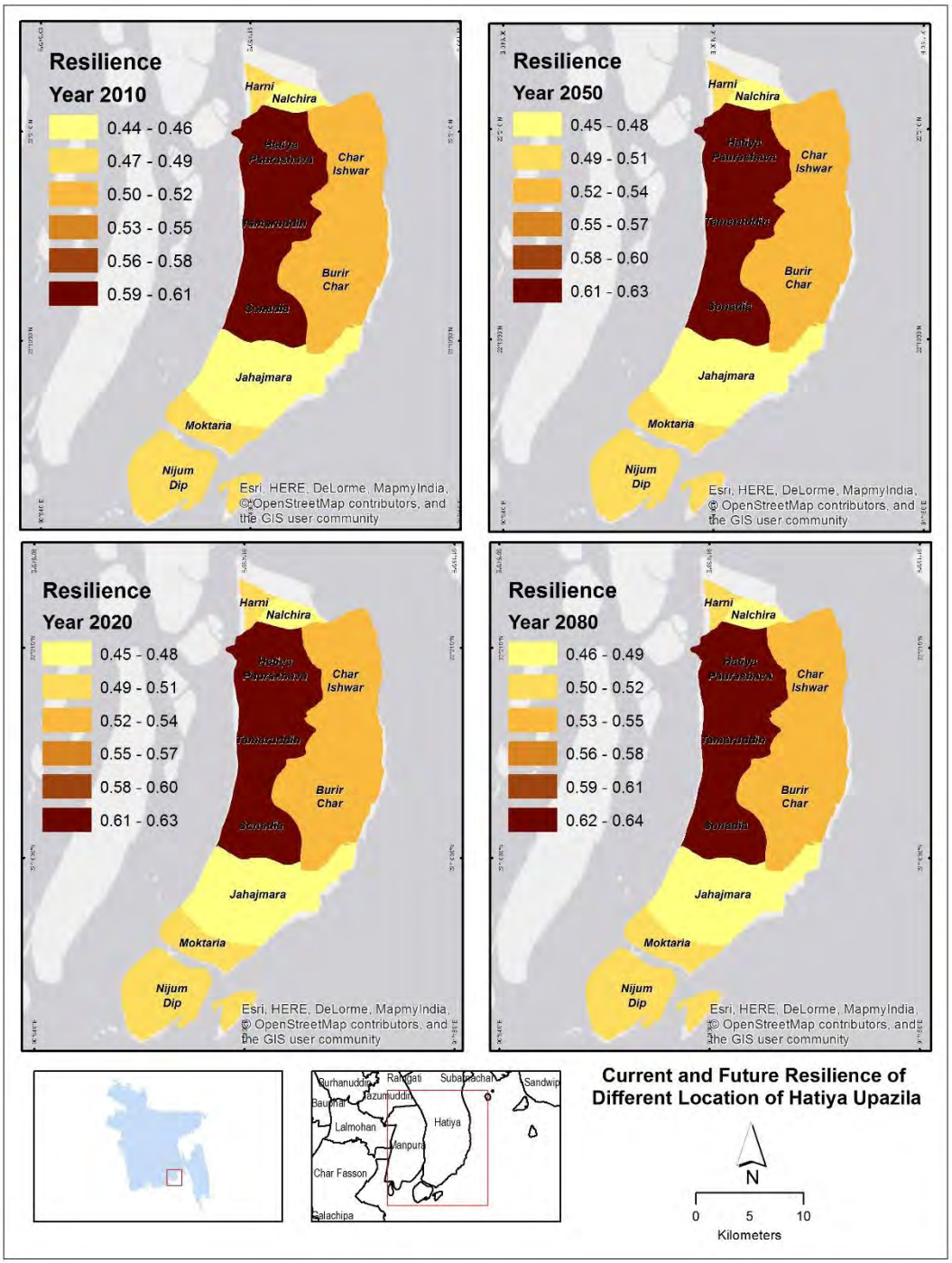

Figure 5.2: Baseline and Future Resilience of Different Locations of Hatiya Upazila

Figure 5.2 is the geographical presentation of baseline and future resilience values. From the above map it has been distinguished that the resilience values have geographic tendency. Middle-western part of Hatiya have higher resilience than the north-east to southern portions. The lowest values are found at Nolchira and Jahajmara, these two locations are very susceptible to natural variables. Nolchira is highly erosion prone area,

where the map is changing year by year. Every year mighty Meghna is eroding thousands of acres of land from the northern part of Hatiya, especially from Norchira. Therefore, this location has lower resilience value. On the other hand, Jahajmara context is different from Nolchira. High depency on natural resources made the location less resilient.

5.3.2 Future Adaptability

Similar to resilience, from economic perspective and recent invention through SSPs an empirical formula (Eqn 4.4) has been proposed in section 4.5.2.7 of this report to assess future adaptability. The formula has two independent variables which are GDP growth rate and baseline adaptability. The baseline adaptability has been determined from direct field survey. And using the Eqn. 4.4 the results have been projected in Table 5-9 for three (2020, 2050, and 2080) time-slices. The results showing steady incremental trends in adaptability of different locations of Hatiya Upazila.

Adaptability and resilience are not directly correlated, but there could be some relation between them. Adaptability has no cluster tendency and it depends on various factors. In this study adaptability is measured using 38 different questions. The adaptability values of different location of Hatiya Upazila at baseline period ranging the between 0.40 and 0.54.

Table 5-9: Baseline and Future Adaptability of Different Locations of Hatiya Upazila

Sl	Area	A (2010)	A (2020)	A (2050)	A (2080)
1	Nijhum Dwip	0.44	0.45	0.45	0.46
2	Moktaria	0.48	0.49	0.49	0.50
3	Jahajmara	0.43	0.44	0.44	0.45
4	Sonadia	0.54	0.56	0.56	0.57
5	Burirchar	0.43	0.45	0.45	0.46
6	Tomoroddi	0.52	0.53	0.54	0.55
7	Char Ishwar	0.45	0.46	0.47	0.47
8	Nolchira	0.40	0.41	0.42	0.42
9	Harni	0.40	0.41	0.41	0.42
10	Hatiya Paurashava	0.49	0.51	0.51	0.52

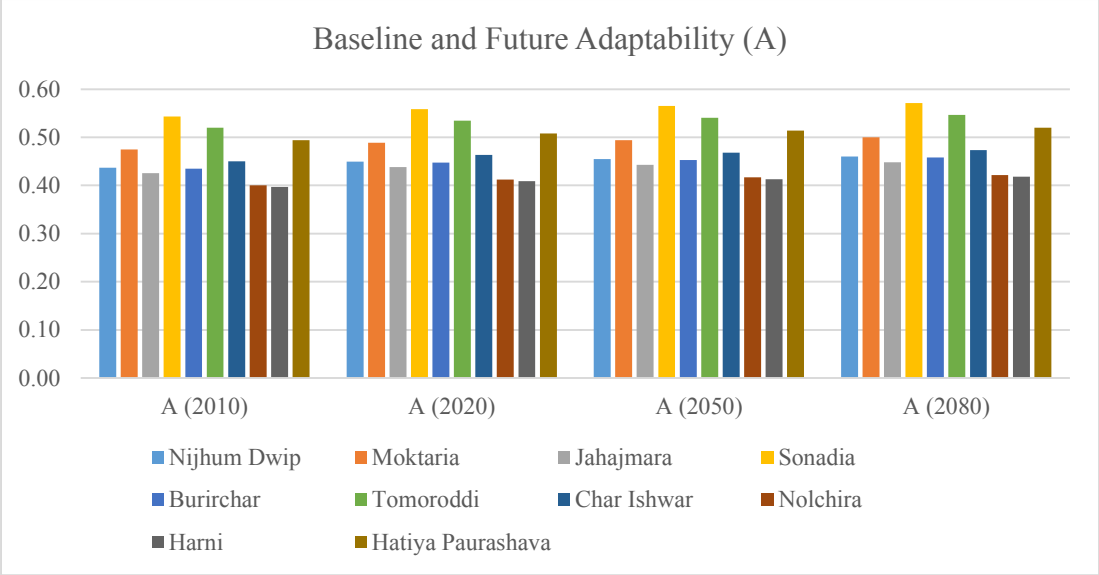

Figure 5.3: Baseline and Future Adaptability of Different Locations of Hatiya Upazila

Figure 5.3 is the graphical illustration of the tabulated (Table 5-9) values of adaptability. Adaptability has also steady incremental trends in Hatiya Upazila as the national GDP growth rate is also incremental. Up to 2020 the slope is higher than the later part of the graph, which means in SSP3 up to 2020 the GDP growth rate is higher than the later part.

Nolchira and Harni are two locations where the adaptability or adaptive capacity is lowest, because of the vulnerable geographic location. Soil erosion made these two locations more vulnerable and along with reduced adaptive capacity. Sonadia and Tomorrodi are the two location where adaptability higher for stable geomorphology and also the other surrounding factors made these places more adaptive than others. As a whole, the graph represented the wide distributed adaptive capacity or adaptability of different locations of Hatiya Upazila, which ranging between 0.40 and 0.54 for baseline period.

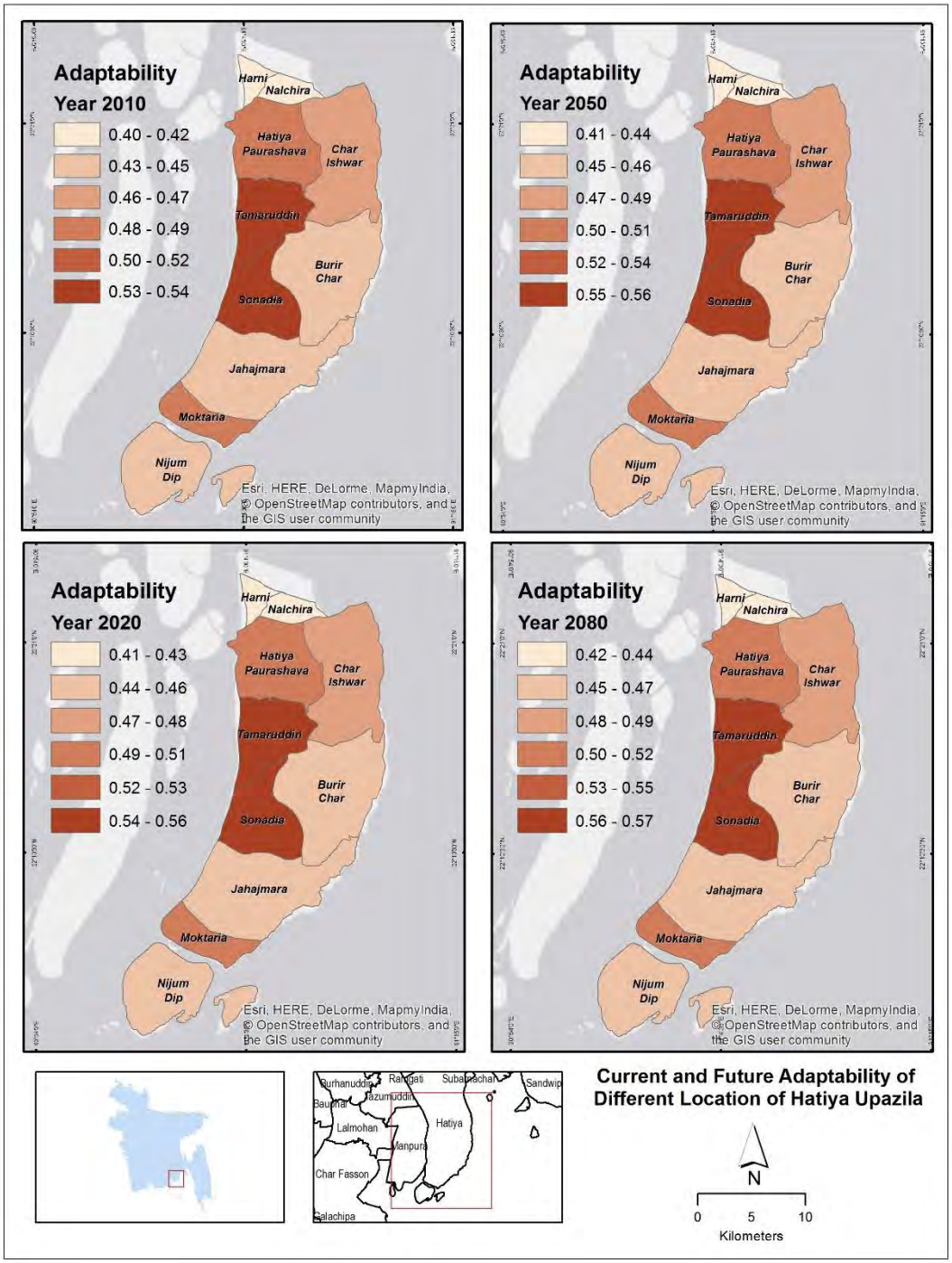

Figure 5.4: Baseline and Future Adaptability of Different Locations of Hatiya Upazila

Figure 5.4 is the GIS based illustration of Table 5-9 information. From this map it has been found the geographic distribution of the adaptability within the Hatiya Upazila. The extreme northern part and south-eastern portions of the Hatiya have lower level of adaptability, which means the higher susceptibility to the climate extremes.

5.3.3 Future Climate Threats Index

Projection of Climate Threat Index (CTI) is purely statistical process, which requires climate model data. At present, research communities are running several climate models and these global models have coarse resolutions. These lower level of resolution is one of the limiting factors in macro or micro planning. For making the global models usable at regional or local level regional models are at operation. In this study, 11 regional model (listed in Table 4-1) downscale data are used to measure projected CTIs. CTI is composite index of eight ETCCDI recommended climate indices namely Warm Spell Duration Index (WSDI), Percentage of days when TX > 90^{th} percentile (TX90P), Annual total PRCP when RR > 99p (R99p), Maximum length of dry spell, maximum number of consecutive days with RR < 1mm (CDD), Maximum length of wet spell, maximum number of consecutive days with RR ≥ 1mm (CWD), Annual total precipitation in wet days (PRCPTOT), Monthly maximum consecutive 5-day precipitation (Rx5day), and Simple precipitation intensity index (SDII). In this study, 11 regional model average data for the point latitude 22.25 longitude 90.75 is taken. As mentioned earlier section, for observed data BMD Hatiya station data were taken. The model grid point is nearest to the Hatiya station felled on land (somewhere in Bhola).

Table 5-10 is showing the results of projected CTI for Hatiya. Up to 2050 CTI has followed sharp incremental trend and following 2050 incremental rate has been changed. The tabulated values are indicating the rapid increase in WSDI and TX90P sub-indices. This is the reflection of dry and hot climatic events will be exacerbated in coming years in Hatiya. From this composite index planners could take decision what sorts of initiatives need to be considered.

Table 5-10: Projected Climate Threat Index (CTI) Derived from Model Data

Sl	Index	CTI (2010) Model	CTI (2020) Model	CTI (2050) Model	CTI (2080) Model
1	WSDI	0.02	0.32	0.86	0.99
2	TX90P	0.10	0.42	0.89	1.00
3	R99p	0.24	0.25	0.29	0.33
4	CDD	0.26	0.27	0.31	0.33
5	CWD	0.47	0.47	0.49	0.54
6	PRCPTOT	0.51	0.46	0.48	0.51
7	RX5day	0.20	0.18	0.21	0.19
8	SDII	0.48	0.45	0.45	0.45
	CTI	**0.29**	**0.35**	**0.50**	**0.54**

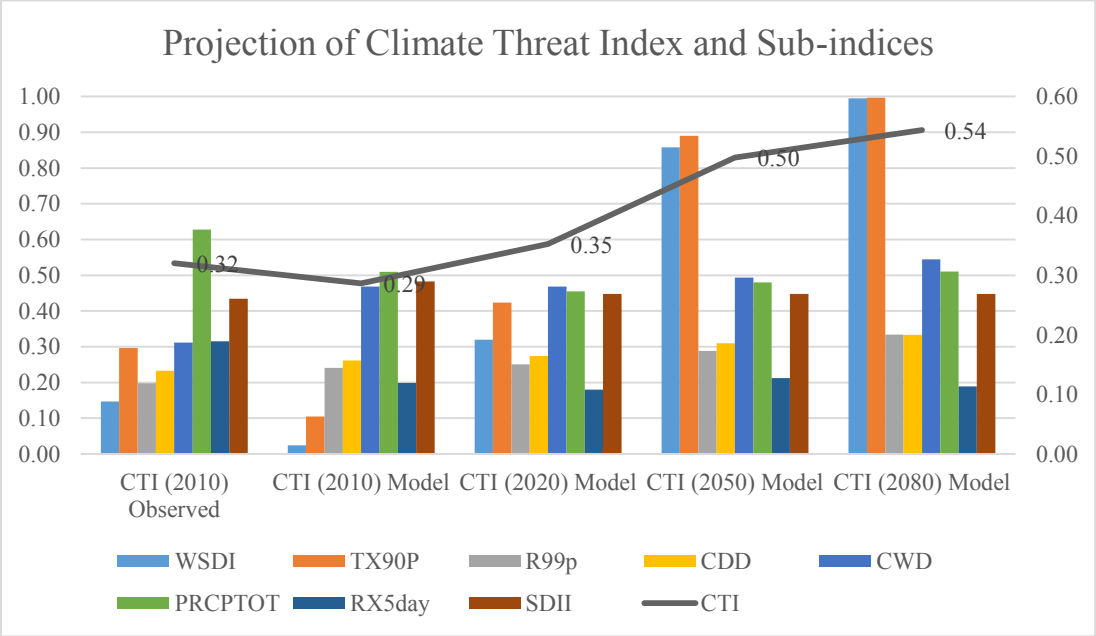

Figure 5.5: Climate Change Index (CTI) and Sub-indices of Hatiya Upazila

Figure 5.5 is the graphical illustration of Table 5-10 values. The graph is very clear about sharp incremental slopes up to 2050. Later on the rate has been reduced to some extent. The upper two lines (WSDI and TX90p) reaching their peaks very quickly to maximum values.

5.3.4 Projected Climate Vulnerability Index

Baseline climate threat index results have been incorporated in section 5.2.3. The ultimate objective of this study is to determine baseline and future climate vulnerability

index with a specified scale (0 to 1). Measuring/assessing the baseline and future vulnerability is comprehensive process, as an outcome of this study the processes have been identified as comprehensive tool to assess climate vulnerability in any other locations. Eqn. 4.1 is the mathematical expression of climate vulnerability index, sub-indices (CTI, R, and A) of this equation are prior need to determine the CVI. Baseline and projected CTIs have been determined through statistical techniques using observed and climate model data. Baseline of other 2 sub-indices (R and A) have been assessed through participatory manner (questionnaire survey) using a close end questionnaire. Then the projected R and A were measured using Eqn. 4.3 and Eqn. 4.4 with the help from IIASA GDP Model growth rate data base.

Table 5-11 is the final result of this study showing the baseline and projected Climate Vulnerability Index (CVI). Vulnerability has been assessed for 10 different locations of Hatiya Upazila. Locations have been selected to cover all sorts of climatic changes distributed over geography. Except the Paurashava the nine locations are peripheral locations of Hatiya regularly facing the different extreme events. Paurashava is located at center of Hitiya which is less impacted by extreme weather events. Table 5-11 is showing that Sonadia, Tomoroddi, and Hatiya Paurashava have least vulnerability and other seven locations have higher vulnerability than the prior three.

Nolchira is the most vulnerable location of Hatiya. During the questionnaire survey the respondent also expressed their concern about Nolchira. The highest value of CVI of Nolchira stated the significance level of this tool. The other three places (Harni, Jahajmara, and Nijhum Dwip) have significantly high vulnerability. The physical survey also supported the same statement for Harni and Nijhum Dwip. Top of the surface, one may notice the difference between physical observation and index result. For supporting the index result there are some strong evidence in questionnaire survey. In the Resilience portion of the questionnaire the weakest part of Jahazmara is natural variable, which made the resilience weaker compare to the other location. On the other hand, in the adaptability portion of the questionnaire relatively weaker socio-cultural cohesion made the Jahazmara less adaptable to climate extremes. Therefore, Jahazmara has become more vulnerable to climate change.

In the general, around the central or middle-western portion of Hatiya Upazila where basic services and utilities are comparatively more available are less vulnerable to climate change at baseline and in future. The extreme north to south-eastern locations including Nijhum Dwip are more vulnerable to climate change due to their geographic location and socio-cultural and economic factors.

Table 5-11: Baseline and Projected Climate Vulnerability Index (CVI)

Sl	Area	CVI (2010) Observed	CVI (2010) Model	CVI (2020) Model	CVI (2050) Model	CVI (2080) Model
1	Nijhum Dwip	0.17	0.16	0.18	0.26	0.28
2	Moktaria	0.17	0.15	0.18	0.26	0.27
3	Jahajmara	0.18	0.16	0.19	0.27	0.29
4	Sonadia	0.14	0.12	0.14	0.20	0.22
5	Burirchar	0.17	0.15	0.18	0.26	0.27
6	Tomoroddi	0.14	0.13	0.15	0.21	0.22
7	Char Ishwar	0.17	0.15	0.18	0.25	0.27
8	Nolchira	0.19	0.17	0.20	0.28	0.30
9	Harni	0.18	0.16	0.19	0.27	0.29
10	Hatiya Paurashava	0.15	0.13	0.15	0.22	0.23

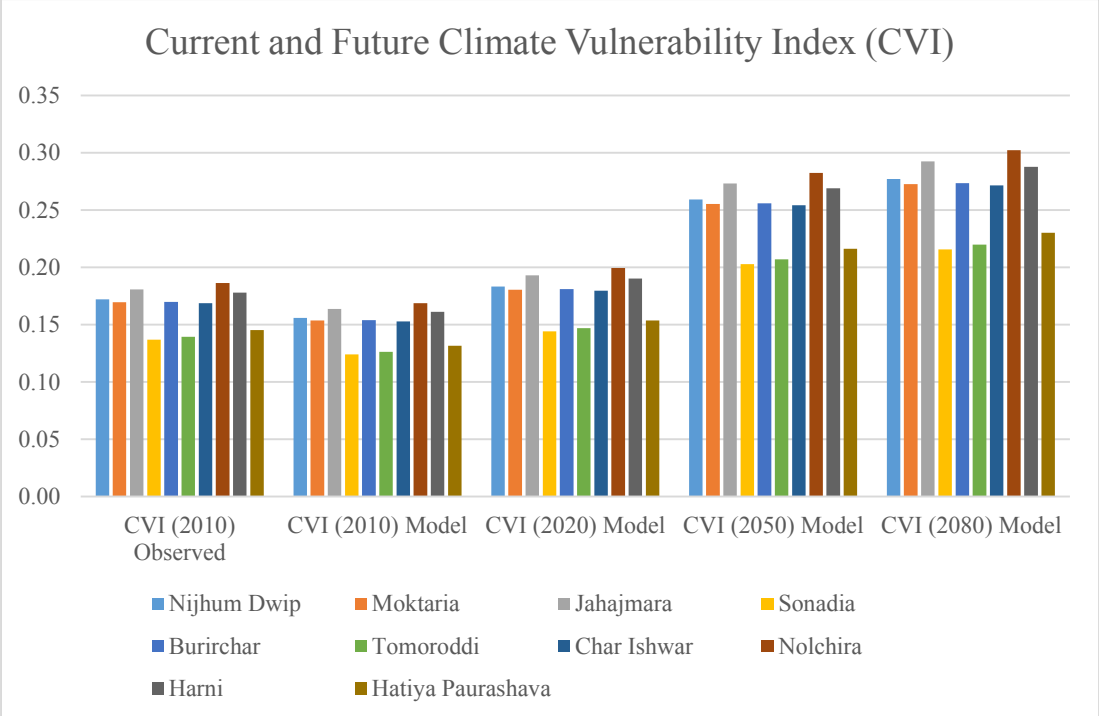

Figure 5.6: Current and Future Climate Vulnerability Index (CVI) of Different Locations of Hatiya Upazila

Figure 5.6 is the illustration of the Table 5-11 values, where CVI incremental trend line is very clear to understand. Vulnerabilities of different locations of Hatiya Upazila has been turned into two clusters. In the lower cluster Sonadia, Tomoroddi, and Hatiya Paurashava incorporated, and in the upper cluster the rest of seven location have made the conjunction.

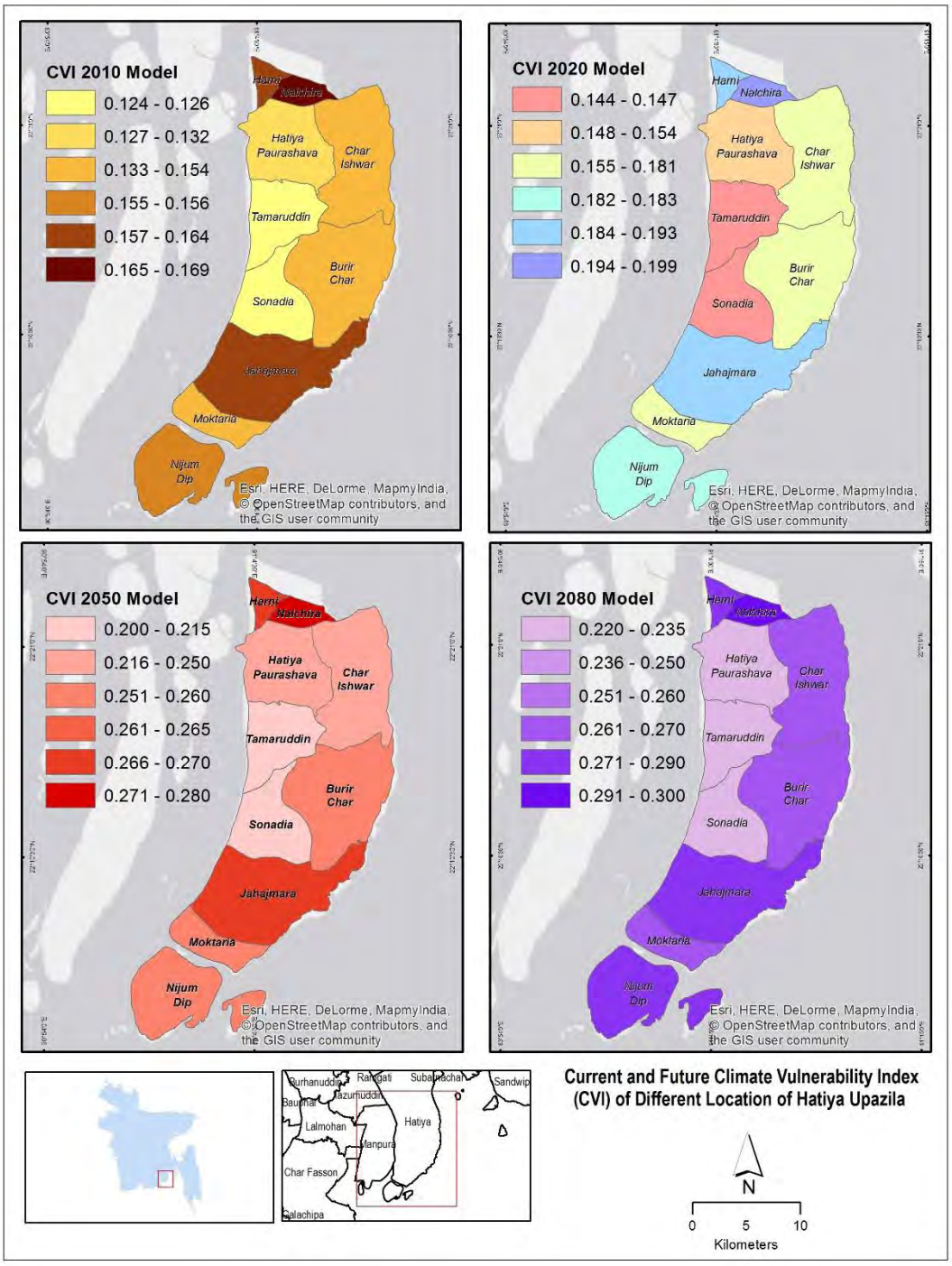

Figure 5.7: Baseline and Future Climate Vulnerability Index (CVI) of Different Locations of Hatiya Upazila

Figure 5.7 is the geographic distribution of the CVI of 10 locations of Hatiya Upazila. From this map the locations and their respective vulnerability is very clear.

5.4 Discussions

The tabulated numbers are not the numbers, each of the numbers have some meaning in the sense of climate vulnerability. For the detection of climate vulnerability of Hatiya Upazila 10 locations were selected, which are i) Hatiya Paurashava, ii) Nalchira, iii) Harni, iv) Tomoroddi, v) Char Ishwar, vi) Sonadia, vii) Burirchar, viii) Jahazmara, ix) Moktaria, and x) Nijhum Dwip. In the list except Moktaria other nine locations are denoting individual Union Parishad jurisdiction. Moktaria is the entry point of Nijhum Dwip in Jahazmara Union. Nalchira and Harni are the two north most Unions of Hatiya and very much susceptible to river erosion and rapidly disappearing in mighty Meghna. Char Ishwar and Burir Char are two eastern Unions exposed to the main channel of Meghna. Tomoroddi and Sonadia are situated at the western part of Hatiya. These two Unions are well connected in road communication directly linked with business growth centers. Jahazmara, Moktaria, and Nijhum Dwip are south most locations of Hatiya lack of road communication and peoples are highly dependent on natural resources. Lastly, Hatiya Paurashava is the central growth center, where urban facilities are comparative better than other locations. The reflection of CVI values were influenced by the whole area for the dispersed respondent location instead of point location. This description is brought to understand the CVI results with a clear sights. In the result section, higher values of CVI are recorded at Nalchira, Harni, and at Nijhum Dwip. On the other hand, lower or least values of CVI are recorded at Sonadia, Tomoroddi, and Hatiya Paurashava. The high vulnerability of the first three locations are due to the geography, high physical hazard threats (high rate of erosion), and high dependency on natural resources made these locations vulnerable. Exception is recorded at Moktaria, which is due to physical protection (coastal embankment), and natural protection (coastal green belt) perceived directly by the respondent. Lower CVI values were recorded for improved communication, better economy, growth center and lower natural resources dependency made the locations less vulnerable. Respondent perceptions have greater influence on this tool. Therefore, the questionnaire enumeration is very crucial for this methods. So far the CVI result is very impressive to assess the effectiveness of the method.

The effectiveness verification could be made more realistically, if the study area were taken additionally one or more locations in the other regions of Bangladesh along with Hatiya. The study has confronted with data availability limitations. More RCPs (at least RCP4.5) data could have positive impact on the study results. In this study on the extreme RCP (RCP8.5) data were taken for biased correction. As the study area is a small coastal island, therefore only one grid point (lat. 22.25 and long. 90.75) at 0.5° resolution were found close to Hatiya station. It has been assumed that the higher the grid points could ensure higher likelihood trends of the model data with observed historical data. The research outcome could be taken to the national level for comprehensive assessment of Climate Vulnerability Index.

CHAPTER 6 : CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The impact of climate change has been increasing day by day, and the measuring local impact or potential threats is essential to plan coping strategy. Throughout the world research community is working to develop new tools for quantifying the impact of climate change. International negotiation platform also wants to see the evidence of the impact of changing climate. At global scale, there are several tools and techniques, but in the local level options are very limited. Developing an effective tool to measure local climate impacts or projecting the impacts was at priority level for Bangladeshi context.

This study has two dimensions, one is quantifying the climate vulnerability at local level and the other one is establishing the process as climate vulnerability index assessment tool to replicate elsewhere. From the research objective point of view the research is successful to address both the dimensions. Primarily, the study has been measured the climate vulnerability index (CVI) through a comprehensive process. The whole process is segregated into two steps, one is statistical data analysis and the other one is participatory process to measure resilience (R) and adaptability (A). The participatory results are also project to different time-slices (2020, 2050, and 2080) through two newly proposed equations. Core impacts of climate change or the climate threat index or exposure is calculated from observed and climate model data. These threats are also projected with the same time-slices. Finally, the CVI is measured with a comprehensive equation using the all three (CTI, R, and A) sub-indices. The results are denoted in the scale of 0 to 1, which means the minimum value of CVI could be 0 and the maximum value could be 1.

The tabulated (Table 5-9) results are the representation of the baseline (2010) and future projection of CVI. In this case, two different results are found for baseline period. One is derived from observed data and the other is from model data (11 different regional model data have been used in this study). Extreme nature of the observed data have given higher values (the CTI value for observed data is 0.32) of CVI compare to the model data (CTI value for model data is 0.29). The model data have given regular

incremental trends of CVI for a particular location. For the baseline model data minimum CVI value was found at Sonadia (0.12) and maximum values was at Nolchira (0.19). In 2020 minimum values was found at Sonadia (0.14) and the maximum value was at Nolchira (0.20). In 2050 minimum value was at Sonadia (0.20) and maximum value was at Nolchira (0.28). Lastly, in 2080 minimum values were at Sonadia and Tomoroddi (0.22) and maximum value was at Nolchira (0.30).

From the above summary, the study results could summarize that the most vulnerable location of Hatiya is Nolchira and least vulnerable locations are Sonadia and Tomoroddi. The study has also revealed some critical issues, which are-

1. geography is not the standalone determinant factor to influence CVI;
2. social and cultural cohesion is very import to reduce vulnerability;
3. improve institutional performance can reduce climate vulnerability.

Lastly, policy makers can use this tools as decision support tool to assess the nationwide climate vulnerability. There is always some improvement option in this tool for wider use.

6.2 Recommendations

For further improvement of the study and make the results more usable the following recommendations are being made on the experience and study results:

1. In this study the study area was confined to coastal island (Hatiya) due to time and resource limitation. For better verification of the comprehensive method of Climate Vulnerability Index (CVI), at least two or more area could be taken for better authentication.
2. In this study only RCP8.5 bias corrected data were used to assess future Climate Threat Index. Use of other RCP data (at least RCP4.5) could make the study more comprehensive.
3. Further development of the equations for determining future resilience and adaptability could be the major contribution to the global research community.
4. For assessing the climate vulnerability index for Bangladesh, this comprehensive tool can play a vital role.

LIST OF REFERENCES

[1] E. . L. Tompkins and W. N. Adger, "Does Adaptive Management of Natural Resources Enhance Resilience to Climate Change?," *Ecology and Society ,* vol. 9, no. 2, 2004.

[2] A. Ali, "Climate change impacts and adaptation assessment in Bangladesh," *Inter Research ,* vol. 12, no. Climate Research , pp. 109-116, 1999.

[3] M. M. Alam , M. A. Hossain and S. Shafee, "Frequency of Bay of Bengal Cyclonic Storms and Depressions Crossing Different Coastal Zones," *International Journal of Climatology ,* vol. 23, pp. 1119-1125, 2003.

[4] Y. Saito and K. McInnes , "Cross-chapter box on building long-term resilience from tropical cyclone disasters," in *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, F. B. Christopher , V. R. Barros, D. J. Dokken, K. J. Mach, M. D. Mastrandrea, T. E. Bilir, M. Chatterjee, K. L. Ebi, Y. O. Estrada, R. C. Genova, B. Girma, E. S. Kissel, A. N. Levy, S. MacCracken, P. R. Mastrandrea and L. L. White, Eds., Cambridge, United Kingdom and New York, NY, USA, Cambridge University Press, 2014, pp. 147-148.

[5] R. V. Cruz, H. Harasawa, M. Lal, S. Wu, Y. Anokhin, B. Punsalmaa, Y. Honda, M. Jafari, C. Li and N. H. Ninh, "Asia. Climate Change 2007: Impacts, Adaptation and Vulnerability," in *Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge, UK, Cambridge University Press, 2007, pp. 469-506.

[6] MoEF, National Adaptation Programme of Action (NAPA), Dhaka, Bangladesh : Ministry of Environment and Forest , 2009.

[7] MoEF, Bangladesh Climate Change Strategy and Action Plan (BCCSAP), Dhaka, Bangladesh : Ministry of Environment and Forest , 2009.

[8] P. P. Wong , I. J. Losada, J. -P. Gattuso, J. Hinkel, A. Khattabi, K. L. McInnes, Y. Saito and A. Sallenger , "Coastal Systems and Low-Lying Areas," in *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment*

Report of the Intergovernmental Panel on Climate Change, Cambridge, United Kingdom and New York, NY, USA, Cambridge University Press, 2014, pp. 364-384.

[9] J. M. Clark, H. G. Orr, J. Freer, J. I. House, P. Smith and C. Freeman , "Assessment of projected changes in upland environments using simple climatic indices," *Inter Research,* vol. 45, no. Climate Research, pp. 87-104, 2010.

[10] T. R. Karl , R. W. Knight , D. R. Easterling and R. G. Quayle, "Indices of Climate Change for United States," *Bulletin of the American Meteorological Society ,* vol. 77, no. 2, pp. 279-292, 1996.

[11] J. Hansen, M. Sato, J. Glascode and R. Ruedy, "A common-sense climate index: Is climate changing noticeably?," *The National Academy of Sciences,* vol. 95, no. Geophysics , pp. 4113-4120, 1998.

[12] UNDP, The Adaptation Policy Framework for Climate Change, Cambridge, UK: Cambridge University Press, 2005.

[13] M. Y. Aguilar, T. R. Pacheco, J. M. Tobar and J. C. Quiñónez, "Vulnerability and adaptation to climate change of rural inhabitants in the central coastal plain of El Salvador," *Inter Research ,* vol. 40, no. Climate Research , pp. 187-198, 2009.

[14] Z. H. Khan, M. S. Masud, T. K. Magumdar, M. M. Hasan, S. Akhter, U. Mahamud, T. Ahmed and L. Banik, "Climate Change Prediction Modelling Impact Assessment of Climate Change and Sea Level Rise on Monsoon Flooding," Climate Change Cell, Department of Environment (DoE), Bangladesh, Dhaka, 2008.

[15] S.-u. Huq, A. U. Ahmed and K. Rob, "Vulnerability of Bangladesh to Climate Change and Sea Level Rise," in *Climate Change and World Food Security*, Berlin Heidelberg, Springer, 1996, pp. 347-379.

[16] Y. Taguchi, M. A. Hussain, Y. Tajima, M. A. Hossain , S. Rana, A. M. S. Islam and M. A. Habib, "Detecting Recent Coastline Changes around the Urir Char Island at the Eastern Part of Meghna Estuary Using Palsar Images," *4th International Conference on Water & Flood Management (ICWFM-2013),* pp. 451-459, 2013.

[17] IPCC, "Appendix I: Glossary," in *Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change*, A. Baede, Ed., Cambridge, United Kingdom, Cambridge University Press, 2001, pp. 788-789.

[18] A. Baede, E. Ahlonsou, Y. Ding and D. Schimel, "The Climate System: an Overview," in *Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge, United Kingdom, Cambridge University Press, 2001, p. 87.

[19] S. Planton, "Annex III: Glossary," in *Climate Change 2013: The Physical Science Basis. Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.*, T. F. Stocker, D. Qin, G. -. Plattner, M. M. Tignor, S. K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P. M. Midgley, Eds., Cambridge, United Kingdom and New York, NY, USA, Cambridge University Press, 2013, pp. 1447-1464.

[20] ISDR, "Annex 1: Terminology: Basic terms of disaster risk reduction," in *Living with Risk. A global review of disaster reduction initiatives.Volume II Annexes*, New York, US and Geneva, Switzerland , International Strategy for Disaster Reduction , 2004, pp. 1-7.

[21] R. Moss, M. Babiker, S. Brinkman, E. Calvo, T. Carter, J. Edmonds, I. Elgizouli, S. Emori, L. Erda, K. Hibbard, R. Jones, M. Kainuma, J. Kelleher, J. F. Lamarque, M. Manning, B. Matthews, J. Meehl, L. Meyer, J. Mitchell, N. Nakicenovic, B. O'Neill, R. Pichs, K. Riahi, S. Rose, P. Runci, R. Stouffer, D. v. Vuuren, J. Weyant, T. Wilbanks , J. P. v. Ypersele and M. Zurek, "Towards New Scenarios for Analysis of Emissions, Climate Change, Impacts, and Response Strategies," Intergovernmental Panel on Climate Change, Geneva, 2008.

[22] Wikipedia, "Wikipedia," 1 December 2011. [Online]. Available: https://en.wikipedia.org/wiki/Representative_Concentration_Pathways. [Accessed 25 November 2015].

[23] IPCC, "Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report

of the Intergovernmental Panel on Climate Change," Cambridge University Press , Cambridge and New York, 2013.

[24] B. Walker, C. S. Holling, S. R. Carpenter and A. Kinzig, "Perspective Resilience, Adaptability and Transformability in Social–ecological Systems," *Ecology and Society,* vol. 9, no. 2, 2004.

[25] IPCC, "Annex II: Glossary," in *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge, United Kingdom and New York, NY, USA , Cambridge University Press , 2014, pp. 1757-1775.

[26] C. Sullivan and J. Meigh, "Targeting attention on local vulnerabilities using an integrated index approach: the example of the Climate Vulnerability Index," *Water Science and Technology ,* vol. 51, pp. 69-78, 2005.

[27] R. E. Kasperson, J. X. Kasperson and . K. Dow , "Vulnerability, equity, and global environmental change," in *Global Environmental Risk* , United Nations University Press and Earthscan , 2001, pp. 247-272 .

[28] UNDHA, "Internationally agreed glossary of basic terms related to Disaster Management," International Decade for Natural Disaster Reduction , Geneva , 1992.

[29] IPCC, "Glossary of Terms," in *Climate Change 2001: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge, United Kingdom, Cambridge Press, 2001, pp. 982-996.

[30] W. N. Adger, N. Brooks, G. Bentham, M. Agnew and S. Eriksen, "New indicators of vulnerability and adaptive capacity," Tyndall Centre for Climate Change Research, Norwich, United Kingdom, 2004.

[31] CARE, "Community-Based Adaptation Toolkit," June 2010. [Online]. Available: http://www.careclimatechange.org/tk/cba/en/cba_basics/key_concepts.html. [Accessed 23 November 2015].

[32] T. R. Karl and R. W. Knight, "The 1995 Chicago Heat Wave: How Likely Is a Recurrence?," *Bulletin of the American Meteorological Society,* vol. 78, no. 6, pp. 1107-1119, 1997.

[33] G. A. Meehl, F. Zwiers, J. Evans, T. Knutson, L. Mearns and P. Whetton, "Trends in Extreme Weather and Climate Events: Issues Related to Modeling Extremes in Projections of Future Climate Change," *Bulletin of the American Meteorological Society,* vol. 81, no. 3, pp. 427-436, 2000.

[34] D. R. Easterling, J. Evans, P. Y. Groisman, T. R. Karl, K. Kunkel and P. Ambenje, "Observed Variability and Trends in Extreme Climate Events: A Brief Review," *Bulletin of the American Meteorological Society,* vol. 81, pp. 417-425, 2000.

[35] R. P. Allan and B. J. Soden, "Atmospheric Warming and the Amplification of Precipitation Extremes," *Science,* vol. 321, pp. 1481-1484, 2008.

[36] E. Lu, W. Higgins, K. Mo and M. Halpert, "A Method for Identifying the Events That Can Best Become Extremes," *Science and Technology Infusion Climate Bulletin, NOAA,* vol. 36th NOAA Annual Climate Diagnostics and Prediction Workshop , pp. 41-47, 2011.

[37] T. R. Karl , N. Nicholls and A. Ghazi , "CLIVAR/GCOS/WMO Workshop on Indices and Indicators of Climate Extremes: Workshop Summary," in *Climatic Change*, Asheville, 1999.

[38] T. C. Peterson, C. Folland, G. Gruza, W. Hogg, A. Mokssit and N. Plummer, "Report on the Activities of the Working Group on Climate Change Detection and Related Rapporteurs," WMO, Geneve, 2001.

[39] A. M. K. Tank, F. W. Zwiers and X. Zhang, Guidelines on Analysis of extremes in a changing climate in support of informed decisions for adaptation, Geneva: World Meteorological Organization, 2009.

[40] S. Nowreen, S. B. Murshed, A. K. M. S. Islam, B. Bhaskaran and M. A. Hasan, "Changes of rainfall extremes around the haor basin areas of Bangladesh using multi-member ensemble RCM," *Theoretical and Applied Climatology,* vol. 119, p. 363–377, 2015.

[41] J. V. Revadekar, S. K. Patwardhan and K. R. Kumar, "Characteristic Features of Precipitation Extremes over India in theWarming Scenarios," *Advances in Meteorology,* vol. 2011, pp. 1-11, 2011.

[42] B. C. O'Neill, E. Kriegler, K. Riahi, K. L. Ebi, S. Hallegatte, T. R. Carter, R. Mathur and D. P. v. Vuuren, "A new scenario framework for climate change research: the concept of shared socioeconomic pathways," *Climatic Change,* vol. 122, p. 387–400, 2014.

[43] H.-M. Füssel and R. J. T. Klein, "Climate Change Vulnerability Assessments: An Evolution of Conceptual Thinking," *Climatic Change,* vol. 75, no. 3, pp. 301-329, 2006.

[44] H.-M. Füssel, "Vulnerability: A generally applicable conceptual framework for climate change research," *Global Environmental Change ,* vol. 17, no. 2, p. 155–167 , 2007.

[45] M. B. Hahn, A. M. Riederer and S. O. Foster, "The Livelihood Vulnerability Index: A pragmatic approach to assessing risks from climate variability and change—A case study in Mozambique," *Global Environmental Change,* vol. 19, no. 1, p. 74–88, 2009.

[46] S. Huq, Z. Karim, M. Asaduzzaman and F. Mahtab, Vulnerability and Adaptation to Climate Change for Bangladesh, Netherlands: Springer, 1999.

[47] IUCN and CNRS, "Adaptation Management Plan for Hatiya Upazila (Sukchar and Burirchar Union)," Ministry of Environment and Forest, Government of the People's Republic of Bangladesh, Dhaka, 2011.

[48] BBS, "Bangladesh Population Census-2001: Community Series, District: Noakhali," Bangladesh Bureau of Statistics (BBS), Planning Division, Ministry of Planning, Government of People's Republic of Bangladesh , Dhaka , 2006.

[49] A. M. K. Uddin and M. S. Iftekhar , "District Information: Noakhali," Programme Development Office, Integrated Coastal Zone Management Project , Water Resources Planning Organization, Ministry of Water Resources, Government of the People's Republic of Bangladesh, Dhak, 2005.

[50] Banglapedia, "Banglapedia," 2006. [Online]. Available: http://www.banglapedia.org/httpdocs/HT/C_0138.HTM. [Accessed 14 December 2014].

[51] D. Quadir and M. A. Iqbal, "Tropical Cyclones: Impacts on Coastal Livelihoods: Investigation of the Coastal Inhabitants of Bangladesh," IUCN Bangaldesh Country, Dhaka, 2008.

[52] D. Quadir, A. Rahman, S. Osman, G. C. Saha and S. Bhatacharjee, "Final Report of the project on 'Initial National Communication in Response to the UN Framework Conventions on Climate Change (UNFCCC)," Ministry of Environment and Forest, Government of Peoples Republic of Bangladesh, Dhaka, 2002.

[53] S. Karmaker and M. M. Shrestha, "Recent climate change in Bangladesh," SAARC Meteorological Research Centre (SMRC), Dhaka, 2000.

[54] A. M. K. Uddin and R. Kaudstaal , "Delineation of the Coastal Zone, Working Paper (WP005)," Program Development Office for Integrated Coastal Zone Management Plan (PDO-ICZMP), Dhaka, 2003.

[55] P. Commission, "Multipurpose Cyclone Shelter Programme: Final Report," Planning Commission, Government of Bangladesh, United Nations Development Programme / World Bank. Project No – UNDP / World Bank / GOB Project – BGD-91/025, Dhaka , 1993.

[56] G. P. Weedon , S. Gomes , P. Viterbo, W. J. Shuttleworth, E. Blyth , H. Osterle, J. C. Adam , N. Bellouin , O. Boucher and M. Best , "Creation of the WATCH Forcing Data and Its Use to Assess Global and Regional Reference Crop Evaporation over Land during the Twentieth Century," *Journal of Hydrometeorology,* vol. 12, pp. 823-848, 2011.

[57] M. G. Grillakis, A. G. Koutroulis and I. . K. Tsanis, "Multisegment statistical bias correction of daily GCM precipitation output," *Journal of Geophysical Research: Atmospheres,* vol. 118, p. 3150–3162, 2013.

[58] N. Brooks, "Vulnerability, risk and adaptation: A conceptual framework," *Tyndall Centre for Climate Change Research,* vol. 38, pp. 1-16, 2003.

[59] B. Smit, I. Burton, R. J. Klein and R. Street, "The Science of Adaptation: A Framework for Assessment," *Mitigation and Adaptation Strategies for Global Change,* vol. 4, no. 3, pp. 199-213, 1999.

[60] Madhuri , H. R. Tewari and P. K. Bhowmick, "Livelihood vulnerability index analysis: An approach to study vulnerability in the context of Bihar," *Journal of Disaster Risk Studies,* vol. 6, no. 1, pp. 1-13, 2014.

[61] M. Bruneau, S. E. Chang, R. T. Eguchi, G. C. Lee, T. D. O'Rourke, A. M. Reinhorn, M. Shinozuka, K. Tierney, W. A. Wallace and D. v. Winterfeldt, "A Framework to Quantitatively Assess and Enhance the Seismic Resilience of Communities," *Earthquake Spectra,* vol. 19, no. 4, pp. 733-752, 2003.

[62] B. L. I. Turner , R. E. Kasperson, P. A. Matson, J. J. McCarthy, R. W. Corell, L. Christensen, N. Eckley, J. X. Kasperson, A. Luers, M. L. Martello, C. Polsky, A. Pulsipher and A. Schiller, "A framework for vulnerability analysis in sustainability science," *Proceedings of the National Academy of Sciences,* vol. 100, no. 14, pp. 8074-8079, 2003.

[63] G. A. Wilson, "Community resilience, globalization, and transitional pathways of decision-making," *Geoforum,* vol. 43, no. 6, pp. 1218-1231, 2012.

[64] B. I. Turner, "Vulnerability and resilience: Coalescing or paralleling approaches for sustainability science?," *Global Environmental Change,* vol. 20, pp. 570-576, 2010.

[65] G. C. Gallopín, "Linkages between vulnerability, resilience, and adaptive capacity," *Global Environmental Change,* vol. 16, no. 3, p. 293–303, 2006.

[66] UNDRO, "Natural Disasters and Vulnerability Analysis," UNDRO, Geneva, 1980.

[67] R. Chambers and G. R. Conway, "Sustainable Rural Livelihoods: Practical Concepts for the 21st Century," Institute of Development Studies, Brighton, 1992.

[68] S. B. Manyena , "Disaster Resilience in Development and Humanitarian Interventions," in *School of Applied Sciences, University of Northumbria*, Newcastle, 2009.

[69] J. Caesar, T. Janes, A. Lindsay and B. Bhaskaran, "Temperature and precipitation projections over Bangladesh and the upstream Ganges, Brahmaputra and Meghna systems," *Environmental Science: Processes & Impacts: The Royal Society of Chemistry,* vol. 17, p. 1047–1056, 2015.

[70] W. G. Cochran , Sampling Techniques, Third Edition ed., New York: John Wiley & Sons, 1977.

[71] Wikipedia, "wikipedia.org," Wikipedia , [Online]. Available: https://en.wikipedia.org/wiki/Sampling_%28statistics%29#cite_note-MySwedeLohr-7. [Accessed 20 November 2015].

[72] I. Crawford, "Sampling In Marketing Research," in *Marketing Research and Information Systems. (Marketing and Agribusiness Texts - 4)*, Rome, Food and Agriculture Organization of the United Nations , 1997, pp. 36-48.

[73] J. S. Brownstein, T. R. Holford and D. Fish, "A Climate-Based Model Predicts the Spatial Distribution of the Lyme Disease Vector Ixodes scapularis in the United States," *Environmental Health Perspectives,* vol. 111, pp. 1152-1157, 2003.

[74] A. Bowen, S. Cochrane and S. Fankhauser, "Climate change, adaptation and economic growth," *Climate Change,* vol. 113, no. 2, pp. 95-106, 2015.

[75] M. Leimbach, E. Kriegler, N. Roming and J. Schwanitz, "Future growth patterns of world regions – A GDP scenario approach," *Global Environmental Change,* 2015.

[76] IIASA, "SSP Database (Version 1.0)," International Institute for Applied Systems Analysis , 5 May 2015. [Online]. Available: https://secure.iiasa.ac.at/web-apps/ene/SspDb/static/download/ISO3166-1_codes_and_country_names.xlsx . [Accessed 24 October 2015].

[77] Investopedia, "investopedia.com," Investopedia , [Online]. Available: http://www.investopedia.com/terms/c/cagr.asp. [Accessed 19 November 2015].

[78] D. Etkin, E. Haque, L. Bellisario and I. Burton, "An Assessment of Natural Hazards and Disasters in Canada," The Canadian Natural Hazards Assessment Project, 2004.

[79] C. Holling, "Understanding the complexity of economic, ecological, and social systems," *Ecosystems,* vol. 4, pp. 390-405, 2001.

[80] K. Sapountzaki, "Vulnerability management by means of resilience," *Natural Hazards,* pp. 1267-1285, 2012.

ANNEXURE-1: FIELD DATA COLLECTION QUESTIONNAIRE

স্থানীয় জলবায়ু পরিবর্তন বিপন্নতা নিরূপনের উদ্দেশ্যে প্রণয়নকৃত জরিপ প্রশ্ন পত্র (ব্যক্তি পর্যায়ে মতামত প্রদানের জন্য প্রযোজ্য)

Survey Questionnaire for Local Climate Vulnerability Assessment (Prepared for Individual Respondent)

তথ্য সংগ্রহের তারিখ: Data Collection Date:	
উত্তর দাতার নাম: Name of the Resposndent:	বয়স: Age:
লিঙ্গ: Gender:	পেশা: Occupation:
গ্রাম: Village:	ইউনিয়ন: Union:
উপজেলা: Upazila:	জেলা: District:
মোবাইল নাম্বার: Contact Number:	তথ্য সংগ্রহের স্থান: Data Collection Location:

জরিপ প্রশ্ন (জলবায়ু সহিষ্ণুতা) **Survey Question (Climate Resilience)**	**উত্তর** **Answer**				
	খুব খারাপ Very Bad	খারাপ Bad	স্বাভাবিক Normal	ভাল Good	খুব ভাল Very Good
Socio-cultural Variables সামাজিক-সংস্কৃতিক প্রশ্ন					
1. What is the level of Govt. department involvement in your area? আপনাদের এলাকায় সরকারি বিভাগ/দপ্তর কেমন কাজ করে?	সরকারি বিভাগ সম্পর্কে কোন ধারনা নাই No Idea about Govt. Department	সরকারি বিভাগের নাম জানি কিন্তু তাদের কাজ সম্পর্কে ধারনা নাই Only the names are known, nothing but the activity	সরকারি দপ্তরে গেলে সাহায্য পাওয়া যায় Services are available at their premises	সরকারি বিভাগ কিছু প্রকল্পের মাধ্যমে কাজ করে Govt. dept. works through some projects	সরকারি বিভাগ বিভিন্ন প্রকল্পের মাধ্যমে বেশ ভালো কাজ করে Govt. dept. are working through many projects
2. What is the level of NGO driven activities in your area? আপনাদের এলাকায় কেমন এনজিও কর্মকান্ড রয়েছে?	এনজিও'র কোন কর্মকান্ড নেই No NGO activites	ক্ষুদ্রঋণ ছাড়া এনজিও'র কোন কর্মকান্ড নেই No NGO activites except microcredit	স্থানীয় কিছু এনজিও উন্নয়ন কর্মকান্ড করে থাকে Some local NGO's development initiatives	স্থানীয় ও জাতীয় কিছু এনজিও উন্নয়ন কর্মকান্ড করে থাকে Some local & national NGO's have development initiatives	স্থানীয়, জাতীয় ও আন্তর্জাতিক কিছু এনজিও পরিবেশ সংরক্ষণ, জলবায়ু পরিবর্তন ও উন্নয়ন কর্মকান্ড করে থাকে Local, national & international NGOs are implementing activites on environment climate change and local development
3. How often social events take place in your area? আপনাদের এলাকায় কত ঘন ঘন সামাজিক অনুষ্ঠান পালিত হয়?	কখনো কোন সামাজিক অনুষ্ঠান পালিত হয়নি We have never observe any social event	আগে সামাজিক অনুষ্ঠান পালিত হত কিন্তু এখন হয় না Observed in past but not currently	জাতীয় পর্যায়ে সীকৃত সামাজিক অনুষ্ঠান পালিত হয় Nationally recognized social events observation	আঞ্চলিক পর্যায়ে সীকৃত সামাজিক অনুষ্ঠান পালিত হয় Regional recognized social events observation	স্থানীয় ভাবে অনেক সামাজিক অনুষ্ঠান পালিত হয় Several local social events take place

জরিপ প্রশ্ন (জলবায়ু সহিষ্ণুতা) **Survey Question (Climate Resilience)**	উত্তর **Answer**				
	খুব খারাপ Very Bad	খারাপ Bad	স্বাভাবিক Normal	ভাল Good	খুব ভাল Very Good
4. How your society reacts during disaster? প্রাকৃতিক দুর্যোগ হলে আপনারা সামাজিকভাবে কিভাবে মুকাবিলা করেন?	দুর্যোগ মুকাবিলা সম্পর্কে জানি না ও মুকাবিলার জন্য পদক্ষেপ গ্রহন করি না No idea and initiative on disaster risk reduction	দুর্যোগ মুকাবিলা সম্পর্কে জানি কিন্তু পদক্ষেপ গ্রহন করি না Know about DRR, but no action in disaster	পারিবারিক ভাবে কিছু পদক্ষেপ গ্রহন করি Some DRR activities at family level	দুর্যোগ মুকাবিলা সম্পর্কে কিছু না জানলেও প্রথাগত কিছু সামাজিক পদক্ষেপ গ্রহন করি No institutional knowledge but have some indigenous practice	দুর্যোগ মুকাবিলা সম্পর্কে জানি ও সামাজিকভাবে পদক্ষেপ গ্রহন করি Know about DRR and social collective action during disaster
5. How often tourist visit your area? আপনাদের এলাকা দেখার জন্য কেমন পর্যটক আসে?	কোন ধরনের পর্যটন স্থান নেই No tourist spot	পর্যটন স্থান আছে কিন্তু পর্যটক আসে না Have some place but tourist to visit	ব্যক্তি পর্যায়ে কিছু পর্যটক আসে Some tourist at personal interest	পর্যটন সুবিধা না থাকায় সল্প সংখ্যক পর্যটক আসে Few tourist visits for lack of facilities	পর্যটন সুবিধা রয়েছে এবং যথেষ্ট পর্যটক আসে Have facilities and tourist visits
6. How often you receive cyclone warning? আপনারা কত তারাতারি ঘূর্ণিঝড়ের সতর্কতা সংকেত পান?	ঘূর্ণিঝড় সংকেত পাই না এবং ঘূর্ণিঝড় আক্রান্ত হই No cyclone warning and regularly affected	ঘূর্ণিঝড়ের চড়ম বিপদ সংকেত পাই Get the extreme cyclone warning only	রেডিও'র মাধ্যমে সামান্য কিছু লোক সংকেত পাই Few people receives the warning by radio	ইউয়ন বা অন্য কোন প্রতিষ্ঠানের মাধ্যমে সংকেত পাই এবং নিরাপদ আশ্রয়ে যেতে পারি Get the warning through Union Council & could take shelter	ব্যাপকভাবে ঘূর্ণিঝড় সংকেত প্রচার করা হয় এবং সবাইকে আশ্রয়কেন্দ্রে পৌছান হয় Extensive warning system and everyone can get to shelter
7. How frequently delinquency affect your area? আপনাদের এলাকায় কি পরিমান চুরি ডাকাতির ঘটনা ঘটে?	চোর ও ডাকাতের কারণে বিপদাপন্ন অবস্থায় থাকি High delinquency rate	চুরি ও ডাকাতির ঘটনা প্রায় ঘটে Moderate delinquency rate	খুব সামান্য চুরি ও ডাকাতির ঘটনা ঘটে Very few delinquency incident	খুব সামান্য চুরির ঘটনা ঘটে কিন্তু ডাকাতি হয় না Very few incident of theft but no robbery	চুরি ও ডাকাতি কখনো হয় না No delinquency incident
Natural Variables প্রাকৃতিক ঘটনা সম্পর্কিত প্রশ্ন					
8. How often flood affect your area? আপনাদের এলাকায় প্রতি বছর কি বন্যা হয়?	প্রতি বছর বন্যা হয় Every year flooding	প্রতি দুই বছরে বন্যা হয় Every two years flooding	প্রতি পাঁচ বছরে বন্যা হয় Every five years flooding	প্রতি দশ বছরে বন্যা হয় Every ten years flooding	প্রতি বিশ বছরে বন্যা হয় Every twenty years flooding
9. How quick flood water drain out? আপনাদের এলাকায় বন্যার পানি নামতে কত সময় লাগে?	বন্যার পানি এক মাস বা তার অধিক সময় স্থায়ী হয় Flood water stagnate for 1 month	বন্যার পানি সাত থেকে দশ দিন থাকে Flood water stagnate for seven days	বন্যার পানি তিন থেকে পাঁচ দিন থাকে Flood water stagnate for 3 to 5 days	বন্যার পানি এক থেকে দুই দিন থাকে Flood water stagnate for 2 to 3 days	বন্যার পানি সাথে সাথেই নেমে যায় No flood water stagnation
10. How much the soil salinity is? আপনাদের এলাকায় মাটির লবণাক্ততার পরিমান কেমন?	মাটি চরম লবণাক্ত এবং কোন কৃষি বা মৎস্য চাষ করা যায় না Extreme soil salinity and no agri or aquaculture	মাটির লবণাক্তা বেশি স্বল্প মাত্রায় মৎস্য চাষ হলেও কৃষি কাজ করা যায় না High soil salinity and limited scale aquaculture but no agriculture	মাটির লবণাক্ততা স্বাভাবিক Acceptable soil salinity	মাটির লবণাক্ততা স্বাভাবিক এবং কৃষি কর্মকান্ড চলছে Acceptable soil salinity and regular agriculture activities	মাটি কখনো লবণাক্ত হয় না এবং সকল উৎপাদন কর্মকান্ড পরিচালনা করা হয় There is no salinity in soil and have every level of production activity

জরিপ প্রশ্ন (জলবায়ু সহিষ্ণুতা) **Survey Question (Climate Resilience)**	উত্তর **Answer**				
	খুব খারাপ Very Bad	খারাপ Bad	স্বাভাবিক Normal	ভাল Good	খুব ভাল Very Good
11. How often you use ground/tube well water? আপনাদের ভূগর্ভস্থ/টিউবওয়েলের পানির উপর নির্ভশীলতা কেমন?	মিঠা পানির জন্য সম্পূর্ণরূপে নির্ভরশীল Completely dependent for fresh water	গৃহস্থালীর পানির জন্য নির্ভরশীল Dependent for household water only	পানীয় জলের জন্য নির্ভরশীল Dependent for drinking water only	নির্ভরশীল হলেও বিকল্প উৎস্য রয়েছে Dependent but have alternative sources	ভূগর্ভস্থ পানির উপর নির্ভশীলতা নেই No ground water dependency
12. How often you cultivates your land during a year? আপনারা বছরে কত বার বা কি পরিমান জমি চাষ করেন?	এখানে কোন চাষের জমি নেই There are no cultivable lands	সামান্য চাষ উপযোগী জমি থাকলেও চাষ করা যায় না Small number of cultivable lands but no cultivation	কিছু পরিমান চাষ উপযোগী জমি রয়েছে এবং বছরে একবার চাষ করা হয় Small number of cultivable lands and single production in a year	অধিকাংশ মানুষ কৃষির উপর নির্ভরশীর এবং বছরে দুইবার চাষ করা হয় Most of the people dependent on agriculture and double production in a year	সকল মানুষ কৃষি নির্ভর এবং বছরে তিন বা তার অধিক বার চাষ করা হয় Each and every one dependent on agri-farming and triple production in a year
13. How quick the forest/mangrove degrading? আপনাদের এলাকায় বন/কেওরা বাগান থেকে গাছ কাটা হয়?	প্রতিদিন বন থেকে গাছ কাটা হয় এবং কোন ব্যবস্থা গ্রহন করা হয় না Everyday forest losing trees and no action	প্রায় গাছ কাটার ঘটনা ঘটে এবং কোন ব্যবস্থা গ্রহন করা হয় না Very often forest losing trees and no action	স্বল্প গাছ কাটার ঘটনা ঘটে এবং কোন ব্যবস্থা গ্রহন করা হয় না Smal number of tree felling and no action	স্বল্প গাছ কাটার ঘটনা ঘটে এবং ব্যবস্থা গ্রহন করা হয় Smal number of tree felling and authority takes action	সাধারনত গাছ কাটার ঘটনা ঘটে না এবং ঘটলেও ব্যবস্থা গ্রহন করা হয় No tree felling incidents and if happens authority takes action
14. How widely people using chemical fertilizer and pesticides? কি পরিমান রাসায়নিক সার বা কিটনাশক ব্যবহার হয়?	প্রয়োজনের অতিরিক্ত রাসায়নিক সার বা কিটনাশক ব্যবহার করা হয় Highest dependency on chemical fertilizer and insecticides	শতভাগ রাসায়নিক সার বা কিটনাশক ব্যবহার করা হয় 100% farmers use chemical fertilizer and insecticides	জৈব ও রাসায়নিক সারের উপর নির্ভরশীলতা রয়েছে Both bio and chemical fertilizer dependency	জৈব সারের উপর নির্ভর-শীলতা বেশি থাকলেও রাসায়নিক সার ও কিটনাশক ব্যবহার করা হয় Apart from bio-fertilizer some level of chemical fertilizer and insecticides use	জৈব পদ্ধতি ব্যবহার করে কৃষি উৎপাদন করা হয় Agri-production is dependends on organic fertilizer
15. What percentage/portion of people involve in fishing? আপনাদের এলাকার কি পরিমান বা কত অংশ লোক মাছ ধরার সাথে জড়িত?	প্রায় সকল পরিবারই মৎস্য আহরন নির্ভর Every families are depends on capture fishery	অধিকাংশ লোক মাছ ধরে জীবিকা নির্বাহ করে Most of the people depends on capture fishery	উল্লেখযোগ্য সংখ্যক লোক মাছ ধরার সাথে জড়িত A good number of people depends on capture fishery	খুব স্বল্প সংখ্যক লোক মাছ ধরার সাথে জড়িত Small number of people depends on capture fishery	বর্তমানে বা অতীতে কোন লোক মাছ ধরার সাথে জড়িত নেই There are no capture fishery dependency
16. How the coastal embankment protects from flood? আপনাদের এলাকায় উপকূলীয় বেড়িবাঁধের উপকারিতা কেমন?	কোন উপকূলীয় বেড়িবাঁধ নেই There is no coastal embankment	উপকূলীয় বেড়িবাঁধের উচ্চতা যথেষ্ট নয় The height of coastal embankment is not enough	উপকূলীয় বেড়িবাঁধ জোয়াড়ের পানি আটকাতে পারে The coastal embankment is enough to protect tidal water	উপকূলীয় বেড়িবাঁধ জোয়াড়ের পানি আটকাতে পারে ও সশ্য রক্ষা করে The coastal embankment protects from tidal surge and agri lands	উপকূলীয় বেড়িবাঁধ জোয়াড়ের পানি আটকাতে পারে এবং ভিতর থেকে বাহিরে পানি বের করে দিতে পারে The coastal embankment protects from tidal surge and drain-out inside water

জরিপ প্রশ্ন (জলবায়ু সহিষ্ণুতা) Survey Question (Climate Resilience)	উত্তর Answer				
	খুব খারাপ Very Bad	খারাপ Bad	স্বাভাবিক Normal	ভাল Good	খুব ভাল Very Good
17. How the activities are protecting natural resources? আপনাদের এলাকায় প্রাকৃতিক সম্পদ রক্ষায় আপনাদের ভূমিকা কি?	প্রাকৃতিক সম্পদ রক্ষায় কোন কর্মকান্ড নেই There is no initiatives to protect natural resources	ব্যক্তি পর্যায়ে ক্ষুদ্র কর্মক্রম থাকলেও তা উল্লেখযোগ্য নয় Insignificant individual initiatives	কিছু দৃশ্যমান কর্মকান্ড রয়েছে Some visible initiatives	প্রাকৃতিক সম্পদ রক্ষায় প্রাতিষ্ঠানিক কর্মকান্ড রয়েছে কিন্তু সবাই সম্পৃক্ত নয় Institutional initiatives to protect natural resources but limited participation	প্রাকৃতিক সম্পদ রক্ষায় প্রাতিষ্ঠানিক কর্মকান্ড রয়েছে এবং সবাই সম্পৃক্ত Participatory institutional initiatives to protect natural resources
Economic Variables অর্থনীতি বিষয়ক প্রশ্ন					
18. How common the agriculture is? আপনাদের এলাকায় কি পরিমান লোক কৃষির উপর নির্ভরশীল?	কৃষির সাথে কোন লোক সম্পৃক্ত নয় No involvement in agriculture	স্বল্প পরিমান লোক কৃষি কাজ করে Small scale involvement in agriculture	উল্লেখযোগ্য পরিমান লোক কৃষি কাজ করে Significant number of people involved in agriculture	অধিকাংশ লোক কৃষি কাজ করে Most of the people involved in agriculture	প্রায় সকল লোক কৃষি কাজ করে Almost every one involved in agriculture
19. How much you earned from activities other than agriculture? কৃষি ছাড়া অন্যান্য খাত থেকে মানুষ কি পরিমান আয় করে?	কৃষি বহির্ভুত কোন আয়ের উৎস্য নেই There is no income source other than agriculture	কৃষি বহির্ভুত আয়ের উৎস্য থাকলেও তা থেকে আয় হয় না Have exo-agricultural income source but no income	স্থানীয় লোকের আয়ে কৃষির উল্লেখযোগ্য পরিমান অংশ রয়েছে Agriculture have significant impact on local level income	স্থানীয় লোকেরা শুধু পারিবারিক প্রয়োজনে কৃষি কাজ করে Subsistance agriculture only	অধিকাংশ লোকের আয়ের উৎস্য কৃষি বহির্ভুত Most of the people have exo-agricultural income source
20. How much easy to practice agriculture? কৃষি কাজ করা এখানে কতটা সহজ?	এখানে কৃষির জন্য কোন জমি নেই There is no agricultural land	কৃষি জমি থাকলেও তা চাষ করা যায় না Have unproductive agricultural land	স্বল্প পরিমান জমি কৃষির আওতায় রয়েছে Small scale land under agriculture	অধিকাংশ জমি কৃষির আওতায় রয়েছে Most of the land under agriculture	কৃষি কাজ করা সহজ Agricultural is easy practice
21. How beneficial the tractor or other agricultural equipment? বিভিন্ন কৃষি প্রযুক্তি যেমন ট্রাক্টর বা অন্যান্য যন্ত্র ব্যবহার কতটা উপকারী?	কৃষি প্রযুক্তি সম্পর্কে কোন ধারনা নেই No idea about agricultural technology	কৃষি প্রযুক্তি সম্পর্কে ধারনা আছে কিন্তু এটি আমাদের এলাকায় নেই Have idea but not available at local level	কিছু কৃষি প্রযুক্তি ব্যবহার হলেও তা খুব স্বল্প Limited agri-technology available	চাষের জন্য কিছু সংখ্যক লোক ট্রাক্টর ব্যবহার করে Few people use tractor for cultivation	অধিকাংশ লোক ট্রাক্টর এবং সেচ যন্ত্র ব্যবহার করে Most of the people use tractor for cultivation

জরিপ প্রশ্ন (অভিযোজন ক্ষমতা) Survey Question (Adaptability)	উত্তর Answer				
	খুব খারাপ Very Bad	খারাপ Bad	স্বাভাবিক Normal	ভাল Good	খুব ভাল Very Good
Socio-cultural Variables সামাজিক-সংস্কৃতিক প্রশ্ন					
1. How development works have implemented last 10 years? গত দশ বছরে আপনাদের এলাকায় কেমন উন্নয়ন কাজ হয়েছে?	কোন ধরণের উন্নয়ন কাজ হয়নি No development activities	স্বল্প অব-কাঠামোগত উন্নয়ন হয়েছে Limited infrastructural development	রাস্তা, ব্রিজ, কালভার্ট এর উন্নয়ন হয়েছে Development of road, bridge, culvert only	রাস্তা, ব্রিজ, কালভার্ট, স্কুল, বেড়ি বাঁধ, মসজিদ, মন্দির ইত্যাদির উন্নয়ন হয়েছে Development of road, bridge,	সবার অংশগ্রহনে পরিকল্পনার মাধ্যমে সামগ্রিক উন্নয়ন হয়েছে Participatory inclusive development

জরিপ প্রশ্ন (অভিযোজন ক্ষমতা) Survey Question (Adaptability)	উত্তর Answer				
	খুব খারাপ Very Bad	খারাপ Bad	স্বাভাবিক Normal	ভাল Good	খুব ভাল Very Good
				culvert, school, embankment, mosque, temple, etc.	
2. How the development works have contributed to cope with hazard/climate risk? এই সকল উন্নয়ন কাজ প্রাকৃতিক দুর্যোগ বা জলবায়ু পরিবর্তন মুকাবিলায় কেমন ভূমিকা রেখেছে?	উন্নয়নের ক্ষেত্রে প্রাকৃতিক দুর্যোগ বিবেচনায় নেয়া হয়নি No consideration of natural hazards in development	উন্নয়ন কর্মকান্ড দুর্যোগ মুকাবিলায় যথেষ্ট নয় Development activities are not enough for DRR	দুর্যোগ মুকাবিলার পরিকল্পনা থাকলেও তা সম্পূর্ণরূপে বাস্তবায়ন সম্ভব হয়নি Plan for DRR but no implementation	দুর্যোগ মুকাবিলায় উন্নয়ন সহায়ক ভূমিকা পালন করেছে Development helps in DRR	সমন্বিত উন্নয়ন কার্যক্রম বাস্তবায়ন হওয়ায় দুর্যোগ মুকাবিলা করা সম্ভব হয়েছে Comprehensive development to implement DRR
3. How foreign aid available for local development? স্থানীয় উন্নয়নের জন্য কেমন বিদেশি সাহায্য এসেছে?	কখনো কোন বিদেশি সহায্য পাওয়া যায়নি No foreign aid	স্থানীয় পর্যায়ে কোন বিদেশি সহায্যপুষ্ট প্রকল্প নাই No foreign aid supported project at local level	এক বা একাধিক স্বল্প মাত্রার প্রকল্প বাস্তবায়িত হয়েছে One or more limited scale foreign aid supported projects	অবকাঠামো খাতে বিদেশি সাহায্যপুষ্ট প্রকল্প বাস্তবায়িত হয়েছে Foreign aided infrastructural project only	বিদেশি সাহায্যপুষ্ট সমন্বিত প্রকল্প বাস্তবায়িত হয়েছে Foreign aided infrastructural integrated project
4. How the local activities impacted environmental conservation? স্থানীয় বিভিন্ন কার্যক্রম পরিবেশ সংরক্ষণের উপর কেমন প্রভাব ফেলেছে?	স্থানীয় সকল কার্যক্রম পরিবেশ সংরক্ষণ বিরোধী Local activities are anti-conservation	স্থানীয় কার্যক্রমে পরিবেশ সয়রক্ষণ বিবেচনায় নাই No consideration of environmental conservation in local activities	স্থানীয় কার্যক্রমের পরিবেশের উপর নেতিবাচক প্রভাব নেই Local activities have no impacts on conservation	স্বল্প কার্যক্রমে পরিবেশ সংরক্ষণ বিবেচনায় আনা হয়েছে Few activities considered environmental conservation	স্থানীয় পর্যায়ে পরিবেশ সংরক্ষণের কার্যক্রম গ্রহন করা হয়েছে Local driven environmental conservation activities
5. What is the income level of local people? স্থানীয় লোকের মাসিক আয় কেমন?	প্রায় সকল লোকের মাসিক আয় ৩০০০ টাকার কম Almost every people have less than 3000 BDT monthly income	অধিকাংশ লোকের মাসিক আয় ৩০০০ টাকার কম Most of the people have less than 3000 BDT monthly income	স্বল্প পরিমান লোক মাসিক ৩০০০ টাকা আয় করতে পারে Few people capable to earn monthly 3000 BDT	অধিকাংশ লোক ৩০০০ টাকা বা তার বেশি আয় করতে পারে Most of the people capable to earn monthly 3000 BDT or more	প্রায় সকল লোক ৩০০০ টাকা বা তার বেশি আয় করতে পারে Almost every people capable to earn monthly 3000 BDT or more
6. How often the basic services available? মৌলিক সেবাগুলো চাহিদার তুলনায় কেমন পাওয়া যায়?	মৌলিক সেবার চরম ঘাটতি রয়েছে Extreme deficite in basic services	মৌলিক সেবার ঘাটতি রয়েছে Deficite in basic services	দুই একটি সেবা পাওয়া গেলেও অধি কাংশ পাওয়া যায় না Only 1 or 2 basic services are available	স্বল্প সংখ্যক স্কুল থাকলেও চিকিৎসার ব্যবস্থা নেই Few basic services are available but no treatment facilities	কর্মসংস্থান, শিক্ষা ও উন্নত চিকিৎসার ব্যবস্থা রয়েছে Employment, education and improved treatment facilities available
7. How natural resources contributed to the food security? স্থানীয় খাদ্য নিরাপত্তায় প্রাকৃতিক সম্পদের ভূমিকা কেমন?	সকল খাদ্যের জন্য প্রাকৃতিক সম্পদের উপর নির্ভরশীল Natural resources are primary sources of food	খাদ্যের বৃহৎ অংশ প্রাকৃতিক সম্পদ হতে সংগ্রহ করা হয় Majority of food collected from natural resources	আমিষের উৎস্য হিসাবে প্রাকৃতিক উৎস্য হতে মৎস্য আহরণ করা হয় For protein fish are collected from natural sources	নির্ভশীলতা থাকলেও রোধ করা সম্ভব Have dependency but reducable	খাদ্য নিরাপত্তায় প্রকৃতিক সম্পদের ভূমিকা নেই There is no dependency on natural resources for food
8. How often people can get micro-credit? ক্ষুদ্র ঋণ প্রাপ্তির হার কেমন?	ক্ষুদ্র ঋণ প্রদানের কোন প্রতিষ্ঠান নেই	ক্ষুদ্র ঋণ প্রতিষ্ঠান থাকলেও সবার জন্য নয় Some microcredit	প্রয়োজনের তুলনায় স্বল্প সংখ্যক ক্ষুদ্র ঋণ প্রতিষ্ঠান রয়েছে	যথেষ্ট সংখ্যক ক্ষুদ্র ঋণ প্রতিষ্ঠান রয়েছে এবং সুদের হাড় উচ্চ	যথেষ্ট সংখ্যক ক্ষুদ্র ঋণ প্রতিষ্ঠান রয়েছে এবং সুদের হাড় নিম্ন

জরিপ প্রশ্ন (অভিযোজন ক্ষমতা) Survey Question (Adaptability)	উত্তর Answer				
	খুব খারাপ Very Bad	খারাপ Bad	স্বাভাবিক Normal	ভাল Good	খুব ভাল Very Good
	There is no microcredit organization	organization but not for all	Not sufficient numbers of microcredit organizations	Sufficient numbers of microcredit organizations and high interest rate	Sufficient numbers of microcredit organizations and low interest rate
9. How available the public transport is? যোগাযোগের জন্য গণপরিবহন সুবিধা কেমন?	গণপরিবহন কি তা জানি না No idea about public transport	গণপরিবহনের কোন সুযোগ নেই No opportunity for public transport	দূরবর্তি গণপরিবহন ব্যবস্থা রয়েছে Distant public transport available	গণপরিবহন ব্যবস্থা রয়েছে Public transport available	যথেষ্ট রকম গণপরিবহণ ব্যবস্থা রয়েছে Sufficient public transport available
10. How improve the communication system? এলাকার যোগাযোগ ব্যবস্থা কেমন?	এলাকায় যোগাযোগের কোন সড়ক নেই No road for communication	এলাকায় যোগাযোগের কোন পাকা বা ইটের সড়ক নেই No pucca/brick road for communication	এলাকায় ইটের তৈরী স্বল্প সংখ্যক সড়ক রয়েছে Some brick made roads for communication	এলাকার অধিকাংশ সড়ক ইটের বা পাকা Most of the local roads are pucca/brick made	এলাকার সকল সড়ক ইটের বা পাকা All the the local roads are pucca/brick made
11. How much cyclone shelter in your area? আপনাদের এলাকায় ঘূর্ণিঝড় আশ্রয় কেন্দ্রের সংখ্যা কেমন?	ঘূর্ণিঝড় আশ্রয় কেন্দ্র নেই No cyclone shelter	ঘূর্ণিঝড় আশ্রয় কেন্দ্র প্রয়োজনের তুলনায় খুব কম Insufficient cyclone shelters	কিছু সংখ্যক ঘূর্ণিঝড় আশ্রয় কেন্দ্র অব্যবস্থাপনার মধ্যে রয়েছে Few numbers of cyclone shelters with poor management	প্রয়োজনীয় সংখ্যক ঘূর্ণিঝড় আশ্রয় কেন্দ্র রয়েছে Have sufficient number of cyclone shelters	ভালো ব্যবস্থাপনায় ঘূর্ণিঝড় আশ্রয়কেন্দ্র রয়েছে Have sufficient number of cyclone shelters with good management
Natural Variables প্রাকৃতিক ঘটনা সম্পর্কিত প্রশ্ন					
12. How the sedimentation and erosion regulate the land? আপনাদের এলাকায় জমির ভাঙ্গন বা জমির উপর পলি কেমন পড়ে?	প্রতি বছর নদীতে বিস্তীর্ণ এলাকার ঘর ভেঙ্গে যাচ্ছে বা খাল বন্ধ হচ্ছে Every year vast community area are being eroded and channels are being silted up	প্রতি বছর নদীতে ঘর ভেঙ্গে যাচ্ছে বা খাল বন্ধ হচ্ছে Every year houses are being eroded and channels are being silted up	প্রতি বছর নদীতে সামান্য কৃষি জমি ভেঙ্গে যাচ্ছে বা খাল বন্ধ হচ্ছে Every year very few agricultural lands being eroded and channels are being silted up	নদী ভাঙ্গন না থাকলেও পলিতে আবাদি জমি নষ্ট হচ্ছে There is no river erosion but siltation degrading cultivable lands	নদী ভাঙ্গন বা পলির কোন সমস্য নেই There is no river erosion or siltation impact
13. How often the channels/creeks changed its course for sedimentation/erosion? আপনাদের এলাকায় ভাঙ্গন বা জমির উপর পলি পড়ার কারণে খালের কি রকম পরিবর্তন হয়?	সকল খাল বিলিন হয়েছে বা ভরাট হয়েছে All channels have silted up	অধিকাংশ খাল বিলিন হয়েছে বা ভরাট হয়েছে Most of the channels have silted up	খালগুলো ভরাট হয়ে যাচ্ছে Channels are being silted up	খালগুলো স্বাভাবিক প্রাকৃতিক হাড়ে ভরাট হচ্ছে Channels are being silted up normal rates	খালের উপর ভাঙ্গন বা পলির কোন প্রভাব নেই No siltation impacts on channels or khals
14. How often cyclone hit your area? আপনাদের এলাকায় ঘূর্ণিঝড় কেমন হয়?	প্রতি বছর এক বা একাধিক ঘূর্ণিঝড় হয় Every year one or more cyclone hits	প্রতি দুই বছর অন্তর ঘূর্ণিঝড় হয় Every two years cyclone hits	প্রতি পাঁচ বছর অন্তর ঘূর্ণিঝড় হয় Every five years cyclone hits	প্রতি ১০-১৫ বছর অন্তর ঘূর্ণিঝড় হয় Every 10-15 years cyclone hits	প্রতি ২০ বা তার বেশি বছর অন্তর ঘূর্ণিঝড় হয় Every 20 or more years cyclone hits
15. How tidal water affect your area? আপনাদের এলাকায় জোয়ারের পানি কেমন প্রভাব ফেলে?	জোয়ারের পানিতে ছয় মাসের অধিক সময় প্লাবিত থাকে Tidal water stagnant for six month	প্রতিদিন স্বাভাবিক জোয়ারে প্লাবিত হয় Tidal water regularly inundates	কাঁটালের জোয়ারে প্লাবিত হয় Only high tide water inundates	শুধুমাত্র ঘূর্ণিঝড়ের সময় প্লাবিত হয় Only the storm surge inundates	শক্তিশালী ঘূর্ণিঝড়ে প্লাবিত হয় Only extreme storm surge inundates
16. How long surface retain rain water? আপনাদের এলাকায় পুকুর/খালে বৃষ্টির পানি কত দিন থাকে?	সব লবণাক্ত পানি All the surface water are saline	স্বল্প সংখ্যক পুকুরে বর্ষাকালে বৃষ্টির পানি থাকে	পুকুর খালে তিন মাস বৃষ্টির পানি থাকে	পুকুর খালে ছয় মাস বৃষ্টির পানি থাকে	পুকুর খালে সারা বছর বৃষ্টির পানি থাকে

জরিপ প্রশ্ন (অভিযোজন ক্ষমতা) Survey Question (Adaptability)	উত্তর Answer				
	খুব খারাপ Very Bad	খারাপ Bad	স্বাভাবিক Normal	ভাল Good	খুব ভাল Very Good
		In few ponds retain rainwater during monsoon	Ponds and khals retain rainwater for three months	Ponds and khals retain rainwater for six months	Ponds and khals retain rainwater for round the year
17. How fertile your soil? আপনাদের এলাকার জমি কেমন উর্বর?	কোন ফসল উৎপাদন করা যায় না No scope of crop production	স্বল্প কিছু স্থানে অতিরিক্ত সার ব্যবহার করে ফসল উৎপন্ন হয় In few places extensive level of fertilizer applied to crops	কিছু স্থানে রাসায়নিক সার ব্যবহার করে ফসল উৎপন্ন হয় In few places fertilizer applied to crops	অধিকাংশ ফসলি জমিতে নূন্যতম সার ব্যবহার করে ফসল উৎপন্ন হয় In most places the fertilizer applied to crops to be minimal	রাসায়নিক সার ছাড়া ফসল উৎপাদন করা যায় No fertilizer applied to crop production
18. How many type of ecosystem do you see? আপনাদের এলাকায় কত রকম প্রতিবেশ আপনারা দেখে থাকেন?	শুধু মাত্র স্থলজ অথবা জলজ প্রতিবেশ Only terrestrial or aquatic ecosystem	শুধু মাত্র স্থলজ অথবা জলজ প্রতিবেশ Only terrestrial or aquatic ecosystem	স্থলজ ও জলজ প্রতিবেশ Terrestrial and aquatic ecosystem	স্থলজ, জলজ, ম্যানগ্রোভ বা বন্য প্রতিবেশ Terrestrial, aquatic, mangrove or wild ecosystem	স্থলজ, জলজ, ম্যানগ্রোভ বা বন্য প্রতিবেশ Terrestrial, aquatic, mangrove or wild ecosystem
19. How many type of plant and animal species available in your area? আপনাদের এলাকায় কত প্রজাতির উদ্ভিদ ও প্রাণী আছে?	এখানে উদ্ভিদ ও প্রাণীর সংখ্যা খুব কম Number of plant and animal species are very low	এখানে উদ্ভিদ ও প্রাণীর সংখ্যা খুব Number of plant and animal species are low	বাংলাদেশের প্রায় সকল সাধারন উদ্ভিদ ও প্রাণী দেখা যায় All general plant and animal species of Bangladesh available here	বাংলাদেশের প্রায় সকল সাধারন ও বন্য উদ্ভিদ এবং গৃহপালিত প্রাণী দেখা যায় All general and wild plant species and domestic animal species of Bangladesh available here	বাংলাদেশের প্রায় সকল সাধারন ও বন্য উদ্ভিদ এবং গৃহপালিত ও বন্য প্রাণী দেখা যায় All general and wild plant species and domestic and wild animal species of Bangladesh available here
20. What is the rate of change of forest area? আপনাদের এলাকায় বন কি হারে ধ্বংস হচ্ছে?	বনভূমি কেটে সবাই উজার করছে Forests are extracted by every one	কাঠ ও জ্বালানীর জন্য সবাই বনের উপর নির্ভবশীল Everyone is dependent on forest for timber and fuel wood	জ্বালানীর জন্য সবাই বনের উপর নির্ভবশীল Everyone is dependent on forest for fuel wood	স্বল্প মাত্রায় বন ধ্বংস হচ্ছে Forest is degrading in insignificant rate	বনভূমি ধ্বংস হচ্ছে না No forest degradation
21. What percentage/portion of land under forest/mangrove coverage? আপনাদের এলাকায় বনভূমি বা কেওরা বাগানের পরিমান কেমন?	কোন বন নাই There is no forest	শুধু বসত বাড়ির আশেপাশে গাছ রয়েছে Only have homestead forest	বেড়ি বাঁধের বাহিরে বন ছিল কিন্তু দ্রুত কমে যাচ্ছে There was forest outside the embankment and depleting in high rate	বেড়ি বাঁধের বাহিরে বন ছিল কিন্তু ধীরে ধীরে কমে যাচ্ছে There was forest outside the embankment and depleting in slow rate	বেড়ি বাঁধের বাহিরে যথেষ্ট পরিমানে বন রয়েছে There is sufficient forest outside the embankment
22. How forest and rivers/channels help to collect basic amenities? আপনাদের দৈনন্দিন প্রয়োজনীয় উপকরণ সংগ্রহ করতে বন ও নদী কিভাবে সাহায্য করে?	বন ও নদী প্রয়োজনীয় সকল খাদ্য ও জ্বালানী সরবরাহ করে Forest and rivers are the primary source of food and fuel	বন ও নদী প্রয়োজনীয় খাদ্য ও জ্বালানী সরবরাহ করে Forest and rivers supplies required food and fuel	বন থেকে জ্বালানী ও নদী থেকে মাছ সংগ্রহ করা হয় Fuel wood collects from forest and fish from rivers	বন থেকে মাঝে মাঝে জ্বালানী সংগ্রহ করা হয় Fuel wood occationally come from forest	বনের ও নদীর উপর নির্ভশীলতা নাই No dependency on forest and rivers
23. How much fuel wood you collect from forest? আপনারা কি পরিমান জ্বালানী কাঠ বন থেকে সংগ্রহ করেন?	সকলে প্রত্যেক দিনের জ্বালানী কাঠ বন থেকে সংগ্রহ করে Everyone collects fuel	অধিকাংশ লোক বন থেকে প্রত্যেক দিনের জ্বালানী সংগ্রহ করে Most of the people collects	বন থেকে আংশিক জ্বালানী সংগ্রহ করা হয় Fuel wood partially collects from forest	বন থেকে জ্বালাণী সংগ্রহ করা হয় না No fuel wood collection from forest	বন সংরক্ষণে কাজ করা হয় Have some activities on forest conservation

জরিপ প্রশ্ন (অভিযোজন ক্ষমতা) Survey Question (Adaptability)	উত্তর Answer				
	খুব খারাপ Very Bad	খারাপ Bad	স্বাভাবিক Normal	ভাল Good	খুব ভাল Very Good
	wood from forest	fuel wood from forest			
24. How the river and estuary provide aquatic and marine resources? নদী বা মোহনা আপনাদের কেমন জলজ সম্পদ সরবরাহ করে থাকে?	এখানে কোন নদী বা মোহনা নেই There is no river or estuary	এখানে নদী থেকে স্বল্প মাছ পাওয়া যায় কিন্তু মোহনা নেই Small scale fishery resources available in river but no estuary	নদী ও মেহানা আংশিক মৎস্য সম্পদ সরবরাহ করে Rivers and estuaries are partial source of fishery resources	মৎস্য আহরণের জন্য অনেকাংশে নদী ও মোহনার উপর নির্ভরশীল Rivers and estuaries are major source of fishery resources	মৎস্য আহরণের জন্য সম্পূর্ণরূপে নদী ও মোহনার উপর নির্ভরশীল Rivers and estuaries are only source of fishery resources
25. How beautiful the forest and rivers are? আপনাদের বন বা নদীগুলো কত সুন্দর?	প্রাকৃতিক সুন্দর্য মন্ডিত কোন স্থান নেই There is no aesthetic place	ঋতু ভিত্তিক কিছু প্রাকৃতিক সুন্দর্য মন্ডিত স্থান থাকলেও কেউ যায় না There are some seasonal aesthetic places	স্বল্প প্রাকৃতিক সুন্দর্য মন্ডিত স্থান রয়েছে There are some natural aesthetic places	প্রাকৃতিক সুন্দর্য মন্ডিত স্থান রয়েছে এবং ঋতু ভিত্তিক কিছু পর্যটক আসে There are some natural aesthetic places and seasonal tourist come to visit	সারা বছর প্রাকৃতিক সুন্দর্য মন্ডিত স্থান পরিদর্শনে পর্যটক আসে There are some natural aesthetic places and round the year tourist visit
26. How available the forest resources are? বনজ সম্পদ কেমন পাওয়া যায়?	এখানে কোন বন নেই There is no forest	স্বল্প পরিমান বন থাকলেও সম্পদ আহরণের উপযুক্ত নয় Few forest but not for resource collection	সীমিত বনজ সম্পদের সরবরাহ রয়েছে Exist limited forest resources supply	বনজ সম্পদের সরবরাহ ভাল Have good forest resources supply	বনজ সম্পদের সরবরাহ খুব ভাল Have very good forest resources supply
27. How available household safe water? আপনাদের এলাকায় বসত বাড়ীর জন্য নিরাপদ পানীয় জলের প্রাপ্যতা/নিশ্চয়তা কেমন?	নিরাপদ পানীয় জলের কোন উৎস্য নেই No safe drinking water source	দূরবর্তি উন্মুক্ত জলাশয়ের উপর নির্ভরশীল Dependnet on distant drinking water source	দূরবর্তি নির্দিষ্ট নিরাপদ পানীয় জলের উৎসের উপর নির্ভরশীল Dependnet on distant specified safe drinking water source	স্বল্প দুরত্বে নিরাপদ পানীয় জলের উৎস্য রয়েছে Have safe drinking water source within short distance	প্রতিটি বাড়িতে নিরাপদ পানীয় জলের উৎস্য রয়েছে Every households have safe drinking water source
28. How available the water for agriculture? আপনাদের এলাকায় কৃষির জন্য সেচের পানির প্রাপ্যতা/নিশ্চয়তা কেমন?	কৃষি সেচের কোন পানির উৎস নেই No irrigation water source	কৃষি সেচের জন্য শুষ্ক মৌসুমে কোন পানির উৎস নেই No irrigation water source in dry season	কৃষি সেচের জন্য অনেক দুরে কিছু পানির উৎস রয়েছে Have distant irrigation water source	কৃষি সেচের জন্য স্বল্প সংখ্যক পানির উৎস রয়েছে Have few irrigation water source	কৃষি সেচের জন্য পানির উৎস রয়েছে Have irrigation water source
29. How the forest do protects from cyclone? আপনাদের এলাকায় বন আপনাদের ঘূর্ণিঝড় থেকে কিভাবে রক্ষা করে?	ঘূর্ণিঝড় থেকে রক্ষায় কোন বন নেই No forest for cyclone protection	ঘূর্ণিঝড় থেকে রক্ষা পাওয়ার জন্য স্থানীয় বন যথেষ্ট নয় Have insufficient local forest for cyclone protection	ঘূর্ণিঝড় থেকে রক্ষায় বনের ভূমিকা সামান্য Have forest for insignificant cyclone protection	বন সাময়িক ঘূর্ণিঝড় থেকে রক্ষা করে Forest give protection from cyclone temporarily	বন প্রাথমিকভাবে ঘূর্ণিঝড় থেকে রক্ষা করে Forest gives primary cyclone protection
Economic Variables অর্থনীতি বিষয়ক প্রশ্ন					
30. What is the land coverage of agriculture/crop? আপনাদের এলাকায় কৃষি জমির পরিমাণ কেমন?	কৃষির জন্য কোন জমি নেই No agricultural lands	স্বল্প পরিমান এক ফসলি কৃষি জমি রয়েছে Few mono-cultural agricultural lands	স্বল্প পরিমান দো ফসলি কৃষি জমি রয়েছে Few bi-cultural agricultural lands	চাহিদার সমান না হলেও যথেষ্ট রয়েছে Have sufficient but not enough agricultural lands	এলাকার খাদ্য চাহিদা পূরণের জন্য যথেষ্ট কৃষি জমি রয়েছে Have sufficient agricultural lands to meet local food demnads

জরিপ প্রশ্ন (অভিযোজন ক্ষমতা) Survey Question (Adaptability)	উত্তর Answer				
	খুব খারাপ Very Bad	খারাপ Bad	স্বাভাবিক Normal	ভাল Good	খুব ভাল Very Good
31. What is the diversity of livelihoods activities in your area? আপনাদের এলাকায় জীবিকার বৈচিত্র্য কেমন?	এলাকার মানুষ শুধুমাত্র কৃষি বা মৎস্য নির্ভর Local people depends on only agriculture and fisheries	এলাকার মানুষ কৃষি বা মৎস্য নির্ভর Local people agriculture and fishery dependent	এলাকার মানুষ কৃষি বা মৎস্য বহির্ভূত পেশা রয়েছে Local people have exo-agriculture and exo-fishery livelihoods	মানুষ বিভিন্ন পেশার সাথে যুক্ত People involve with various livelihoods	মানুষের বৈচিত্র্যময় পেশা রয়েছে People have diversified livelihoods
32. What percent or portion of people can use tractor or irrigation pump? আপনাদের এলাকায় কি পরিমাণ লোক চাষের জন্য ট্রাক্টর বা সেচের জন্য পাম্প সুবিধা পেয়ে থাকে?	ট্রাক্টর এবং সেচ যন্ত্র সম্পর্কে কোন ধারনা নেই No idea about tractor and irrigation pump	ট্রাক্টর এবং সেচ যন্ত্র সম্পর্কে শুনেছি কিন্তু এর ব্যবহার জানা নাই Heared about tractor and irrigation pump but utility is unknown	স্বল্প সংখ্যক মানুষ ট্রাক্টর এবং সেচ যন্ত্র ব্যবহার করে Few people use tractor and irrigation pump	চাষের জন্য মানুষ ভাড়ার ট্রাক্টর ও সেচ যন্ত্র ব্যবহার করে Few people use rental tractor and irrigation pump	অধিকাংশ লোক ট্রাক্টর এবং সেচ যন্ত্র ব্যবহার করে Most of the people use tractor and irrigation pump
33. What percentage or portion of people use modern agriculture technology? আপনাদের এলাকায় কি পরিমাণ লোক আধুনিক কৃষি প্রযুক্তি ব্যবহার করে?	আধুনিক কৃষি প্রযুক্তি সম্পর্কে কোন ধারনা নেই No idea about modern agricultural technology	আধুনিক কৃষি প্রযুক্তি সম্পর্কে ধারনা আছে কিন্তু এটি আমাদের এলাকায় নেই Have idea about modern agricultural technology but not available at local level	কিছু আধুনিক কৃষি প্রযুক্তি ব্যবহার হলেও তা খুব স্বল্প Use of few modern agricultural tools	চাষের জন্য কিছু সংখ্যক লোক ট্রাক্টর এবং সেচ যন্ত্র ব্যবহার করে Few people use tractor and irrigation pump	অধিকাংশ লোক আধুনিক কৃষি প্রযুক্তি ব্যবহার করে Most of the people use modern agricultural technology
34. What percent or portion of people using irrigation scheme? আপনাদের এলাকায় কি পরিমান লোক সেচ সুবিধা নিয়ে থাকে?	কোন সেচ সুবিধা নেই এবং তা ব্যবহারের ব্যবস্থাও নেই No irrigation scheme and appropriate condition	কোন সেচ সুবিধা নেই No irrigation scheme	ব্যক্তি পর্যায়ে স্বল্প সংখ্যক সেচ যন্ত্র রয়েছে Few private owned irrigation scheme	কিছু সংখ্যক চাষির জন্য সরকারি সেচ ব্যবস্থা রয়েছে Public irrigation scheme for limited farmers	সকল চাষির জন্য সরকারি সেচ ব্যবস্থা রয়েছে Public irrigation scheme for all farmers
35. What percent/portion of people have their own agricultural land? আপনাদের এলাকায় কি পরিমাণ লোকের নিজের কৃষি জমি রয়েছে?	কোন বন্দোবস্তি বা ব্যক্তি মালিকানার কৃষি জমি নেই No leased or private agricultural lands	ব্যক্তি মালিকানার কৃষি জমি না থাকলেও কিছু বন্দোবস্তি কৃষি জমি রয়েছে No private agricultural lands but leased	স্বল্প সংখ্যক লোকের ব্যক্তি মালিকানা ও বন্দোবস্তি কৃষি জমি রয়েছে Few people have private and leased agricultural lands	অধিকাংশ কৃষকের ব্যক্তি মালিকানার কৃষি জমি রয়েছে Most of the people have private agricultural lands	সকল কৃষকের ব্যক্তি মালিকানার কৃষি জমি রয়েছে Every farmers have private agricultural lands
36. What percent/portion of people have taken credit from micro credit organization? আপনাদের এলাকায় কি পরিমাণ লোক ক্ষুদ্র ঋণ সুবিধা গ্রহণ করেছে?	ক্ষুদ্র ঋণ প্রদানের কোন প্রতিষ্ঠান নেই No microcredit organization	ক্ষুদ্র ঋণ প্রতিষ্ঠান থাকলেও সবার জন্য নয় Limited numbers microcredit organization but not for all	প্রয়োজনের তুলনায় স্বল্প সংখ্যক ক্ষুদ্র ঋণ প্রতিষ্ঠান রয়েছে Insufficient numbers of microcredit organization	ক্ষুদ্র ঋণ প্রতিষ্ঠান রয়েছে এবং অধিকাংশ পরিবার ঋণ গ্রহন করেছে Have microcredit organization and most family received loan	যথেষ্ট সংখ্যক ক্ষুদ্র ঋণ প্রতিষ্ঠান রয়েছে এবং প্রায় সকল পরিবার ঋণ গ্রহন করেছে Have sufficient numbers microcredit organization and most family received loan
37. What percent/portion of people have their own homestead?	সকলে খাস জমিতে বসবাস করে	সকলে বন্দোবস্তি জমিতে বসবাস করে	স্বল্প সংখ্যক লোকের নিজের বসতভিটা রয়েছে	অধিকাংশ লোকের নিজের বসতভিটা রয়েছে	সকলের নিজের বসতভিটা রয়েছে

জরিপ প্রশ্ন (অভিযোজন ক্ষমতা) Survey Question (Adaptability)	উত্তর Answer				
	খুব খারাপ Very Bad	খারাপ Bad	স্বাভাবিক Normal	ভাল Good	খুব ভাল Very Good
আপনাদের এলাকায় কি পরিমাণ লোকের নিজের বসতভিটা রয়েছে?	Everyone lives on public lands	Everyone lives on leased lands	Few people have own homestead	Most of the people have own homestead	Everyone have own homestead
38. How often people can go to the market? আপনাদের এলাকার বাজার কত দূরে?	১৫ কিঃমিঃ দুরত্বের মধ্যে কোন বাজার নেই No market within 15km	১০ কিঃমিঃ দুরত্বের মধ্যে বাজার রয়েছে Market within 10km	৫ কিঃমিঃ দুরত্বের মধ্যে বাজার রয়েছে Market within 5km	২ কিঃমিঃ দুরত্বের মধ্যে বাজার রয়েছে Market within 2km	১ কিঃমিঃ বা তার কম দুরত্বের মধ্যে বাজার রয়েছে Market within or less 1km distance

ANNEXURE 2: List of ETCCDMI core Climate Indices

ID	Indicator Name	Definitions	Units
FD0	Frost days	Annual count when TN(daily minimum)<0ºC	Days
SU25	Summer days	Annual count when TX(daily maximum)>25ºC	Days
ID0	Ice days	Annual count when TX(daily maximum)<0ºC	Days
TR20	Tropical nights	Annual count when TN(daily minimum)>20ºC	Days
GSL	Growing season Length	Annual (1st Jan to 31st Dec in NH, 1st July to 30th June in SH) count between first span of at least 6 days with TG>5ºC and first span after July 1 (January 1 in SH) of 6 days with TG<5ºC	Days
TXx	Max Tmax	Monthly maximum value of daily maximum temp	ºC
TNx	Max Tmin	Monthly maximum value of daily minimum temp	ºC
TXn	Min Tmax	Monthly minimum value of daily maximum temp	ºC
TNn	Min Tmin	Monthly minimum value of daily minimum temp	ºC
TN10p	Cool nights	Percentage of days when TN<10th percentile	Days
TX10p	Cool days	Percentage of days when TX<10th percentile	Days
TN90p	Warm nights	Percentage of days when TN>90th percentile	Days
TX90p	Warm days	Percentage of days when TX>90th percentile	Days
WSDI	Warm spell duration indicator	Annual count of days with at least 6 consecutive days when TX>90th percentile	Days
CSDI	Cold spell duration indicator	Annual count of days with at least 6 consecutive days when TN<10th percentile	Days
DTR	Diurnal temperature range	Monthly mean difference between TX and TN	ºC
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

ID	Indicator Name	Definitions	Units
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