Vulnerability of Fisheriesto Climate Change in Bangladesh: A Composite Index Approach

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Masters of Science in Fisheries

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Dedicated to

My entire Family who have been supporting me in all stages of my life

Certificate

This is to certify that this thesis entitled **"Vulnerability of Fisheries to Climate Change in Bangladesh: A Composite Index Approach**" is submitted by Aparna Barman, has been carried out under my supervision. This is further to certify that it is an original work and suitable in partial fulfillment for the degree of Masters in Fisheries, University of Dhaka.

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Abstract

Climatic hazards result unprecedented impacts on natural and human systems especially in low-lying developing countries like Bangladesh. Bangladesh has 64 districts with various levels of fisheries resources but are exposed to multiple climatic hazards that result in vulnerability. However, to date no research has been conducted to measure the district level vulnerability of fisheries to climate variability and change. This study has assessed the levels of vulnerability of fisheries in 64 districts of Bangladesh byselecting indicators of exposure, sensitivity, and adaptive capacity to climate change impact on culture, capture and overall fisheries using a composite vulnerability index approach.In case of culture fisheriesthe very highly vulnerable districts (higher to lower order) are Lalmonirhat, Panchagarh, Nilphamari, Thakurgaon, Satkhira, Kurigram, Dinajpur, Sunamganj, Gaibandha, Lakshmipur, Rangpur and Shariatpur.For the same fisheries the low vulnerable districts are Dhaka, Mymensingh, Chittagong and Comilla. While, for capture fisheries, the very highly vulnerable districts (higher to lower order) are Bhola, Khulna, Gaibandha, Lalmonirhat, Nilphamari, Satkhira, Shariatpur, Kurigram, Patuakhali and Chapai Nawabganj.For the same fisheries the low vulnerable districts are Dhaka, Chittagong, Comilla and Gazipur. Combining the culture and capture fisheries, i.e., for overall fisheries the very highly vulnerable districts (higher to lower order) Shariatpur, Lakshmipur, Kurigram, Bhola, Rangamati, Lalmonirhat, Panchagarh, Sunamganj, Nilphamari, Patuakhali, Gaibandha, Thakurgaon, Chapai Nawabganj, Noakhali, Rajbari and Chandpur. This vulnerability has emerged due to very high/high exposure, moderate sensitivity and low/moderate adaptive capacity.While, for overall fisheries the low vulnerable districts are Dhaka, Comilla, Mymensingh, Chittagong and Jessore. It is interesting to note that the vulnerability of fisheries to climate change varies spatially in Bangladesh: North-Bengal, coastal districts and districts adjacent to the river (especially for capture fisheries) are highly vulnerable, while, most divisional districts are low vulnerable because of their low sensitivity and high/very high capacity to adapt.The findings of this study will allow the policymakers and practitioners to easily identify the most vulnerable districts so as toundertake actionsto decrease the vulnerability and/orensure sustainable adaptation to climate change.

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Acronyms and Abbreviations

BBS	Bangladesh Bureau of Statistics
BDT	Bangladeshi Taka
BOD	Biological Oxygen Demand
BMD	Bangladesh Meteorological Department
BWDB	Bangladesh Water Development Board
°C	Degree Celsius
CEGIS	Center for Environmental and Geographic Information Services
CMIP3	Couple Model Intercomparison Project 3
DFID	Department for International Development
DO	Dissolve Oxygen
DoF	Department of Fisheries
e. g.	exempli gratia
etc.	etcetera
°F	Degree Fahrenheit
FAO	Food and Agricultural Organization
FRSS	Fisheries Resource Survey System
GDP	Gross Domestic Product
GDP	Gross District Product
GIS	Geographic Information System
Ha	Hectare
i.e.	Id est
IPCC	Intergovernmental Panel on Climate Change
mm	Millimeter
MT	Metric Ton
NGO	Non-Government Organization

SPSS	Statistical Package for the Social Sciences
Sq. Km	Square Kilometer
WHO	World Health Organization

Chapter 1: Introduction

1.1 Rationale

Global climate is changing, influencing all spheres of earth including natural, physical, social and economic domains, lives and livelihoods of people (IPCC 2014).The fisheries sector is considered amongst the worst affected by climate change which supports livelihoods of 660-820 million people (FAO 2012). The Intergovernmental Panel on Climate Change (IPCC) predicted that, small scale fishing communities in developing countries (which constitute 90% fishery-dependent people (FAO 2012)), in particular will face complex and localized impacts (IPCC 2007b).Bangladesh has been identified as extremely vulnerable county to climate change impacts because of its geographical location, high population density, high levels of poverty, and the reliance of many livelihoods on climate-sensitive sectors, particularly rural agriculture and fisheries (IPCC 2007b; Met Office 2011; World Bank 2013).Its fisheries sector has been identified as the most vulnerable to climate change in the World (Allison *et al.* 2009), which supports livelihoods of about 17.5 million fishers directly or indirectly and contributes 3.69% of national GDP (Gross Domestic Product) which is 22.60% of the Agricultural GDP (FRSS 2015).Over the past decades, the climate of Bangladesh has been changed and the prediction of Met Office (2011) is that it will continue to change even more in the future, resulting in considerable negative impacts. So fisheries of Bangladesh are vulnerable to climate variability and change.

Bangladesh has 64 districts with variable fisheries resources which are exposed to various climatic hazards. It would be interesting to understand the level of vulnerability at different district due to climate variability and change. Such study can provide important insights to address the enhanced level of future impacts or reduce vulnerability for them. Moreover, vulnerability mapping can allow for improved communication about risks and what is threatened. This study has allowed better visual presentations and understanding of the risks and vulnerabilities by districts in Bangladesh. This vulnerability maps will allow decision-

makers to decide on mitigating measures to prevent or reduce loss of life, injury and environmental consequences before a disaster occurs.

1.2 What is Climate Change?

The climate system is a complex system consisting of atmosphere, land surface, snow and ice, oceans and other bodies of water and living things. Climate is generally described as the mean and variability of temperature, precipitation and wind over a period of time, ranging from months to millions of years (the classical period is 30 years) (IPCC 2007b). According to IPCC (2007b), Climate change refers to any change in climate over time, whether due to natural variability or as a result of human activity (IPCC 2007b). But according to UNFCCC, climate change can be defined 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 (UNFCC undated).Climate change is caused by factors such as biotic processes, variations in solar radiations received by Earth, plate tectonics and volcanic eruptions. Global warming is a significant cause of climate change. In the fifth assessment (AR5) in 2014 the IPCC reported that scientist were more than 95% certain that most of the global warming is caused by increasing concentrations of greenhouse gasses (water vapor, carbon dioxide, methane, nitrous oxide and ozone) and other human activities (i.e., burning fossil fuels, industrialization, etc.)(IPCC 2014).

There are many indicators of climate change which includes physical responses such as changes in the surface temperature, atmospheric water vapor, precipitation, severe events, glaciers, ocean and land ice, and sea level.Developing countries like Bangladesh are vulnerable to climate variability and change and they will suffer from the negative impacts of climate change (IPCC 2001)As a result of climate change Bangladesh faces shocks and stresses like flood, drought, land erosion, sea level rise, cyclones, temperature and rainfall fluctuation etc.

1.3 What is Vulnerability?

The IPCC defined vulnerability as "the degree to which a system is susceptible to, or unable to cope with the adverse effects of climate change, including climate variability and extremes". Thus vulnerability is a function of the character, magnitude, and rate of climate change and variation to which fisheries sector is exposed, its sensitivity and its adaptive capacity (IPCC 2001). According to (Adger 2006), "Vulnerability is the state of susceptibility to harm from exposure to stresses associated with environmental and social change and from the absence of capacity to adapt". Vulnerability of fishery-based livelihoods to climate variability and change can be defined as the degree to which fishery-based livelihood system are susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes (adopted from IPCC 2007b).

Exposure, sensitivity, and adaptive capacity are the key factors that determine the vulnerability of households and communities to the impact of climate variability and change (IPCC 2007b). Here exposure is defined as the nature and degree to which a system is exposed to significant climate variations (IPCC 2007b); sensitivity is the degree to which system is affected either adversely or beneficially, by climate stimuli (IPCC 2007b); and adaptive capacity is the ability of a system to adjust to climate change (including climate variability and extremes), to moderate the potential damage from it, to take advantage of its opportunities, or to cope with its consequences (IPCC 2007b).

1.4 Climate Change and Fisheries: Relations and Impacts

Fisheries and their ecosystem have a deeper and more significant link than those that exists in mainstream agriculture (FAO 2008). The productivity of a fishery is tied to the health and functioning of the ecosystems on which it depends for food, habitat and even reproduction (MAB 2009).A sudden increase in temperature may cause death to fish due to oxygen depletion. As fishes are poikilothermic and ambient water temperature affects them strongly, so the effects of climate change on their physiology and behavior are likely to be particularly

pronounced and widespread, individually in fish growth, metabolism, food consumption, reproductive success and habitat range (Macusi *et al.* 2015).

Climate change is modifying fish distribution and the productivity of marine and freshwater species (Cochrane *et al.* 2009). This has impact on the sustainability of fisheries and aquaculture, on the livelihoods of the communities that depend on fisheries. Diversified range of direct and indirect climate impacts, including displacement and migration of human populations; impacts on coastal communities and infrastructure due to sea level rise; and changes in the frequency, distribution or intensity of tropical storms exposed to fisheries (Daw *et al.* 2009).The effect of sea level rise means that the coastal fishing communities are in the front line of climate change while changing temperature and rainfall patterns and water use impact on inland fisheries and aquaculture.

Climatic and environmental factors affect fish at individual, population and ecosystem level and change in the distribution and of fish and plankton are particularly striking because they are more rapid than the changes occurring in terrestrial fauna and flora(Beaugrand *et al.* 2002; Parmesan and Yohe 2003).A range of direct and indirect impacts on marine and freshwater capture fisheries have been predicted due to climate change, with its implications for fisheries-dependent economics, coastal communities and fisherfolks (Daw *et al.* 2009). The fisheries vulnerability to climate change depends upon the character and the rate of the change, the nature of the fishery and changes in the associated species and habitat. According to Carpenter and Colleagues (1992), climate change invade fisheries by changes in water temperature; the duration and timing of temperature extremes; the pattern and magnitude of annual stream flows; surface water elevation and the shorelines of lakes, reservoirs, and near-shore marina environments (Carpenter *et al.* 1992). In lotic system altered hydrologic regimes and increased groundwater temperature could affect the quality of fish habitat and in lentic system may be exacerbated or offset and stratification will likely become more resolute and dynamic (Ficke *et al.* 2007).

The dynamics of ocean currents, the flow of rivers and the area covered by wetlands are affected by the changes in water temperature and precipitation which effect on ecosystem structure and function and on distribution and production of fish stocks (Mustafa 2010). The safety and efficiency of fishing operations is affected by increased incidence of extreme events such as floods, droughts and storms on coastal and riparian homes, services and infrastructure. Moreover, sea level rise and other large-scale environmental changes will have unpredictable effects on coastal and wetland environments and livelihoods (Allison*et al.* 2005).Coastal habitats and resources are likely to be impacted by sea level rise, warming sea temperatures, eutrophication and invasive species. In general, coastal fishing communities face a double exposure of reduced fisheries resources and increased risk of coastal flooding and storm surges (Badjeck *et al.* 2010). Table 1 is illustrating the ecological, direct and socio-economic impacts of climate change on fisheries.

Apart from negative impacts, some positive impacts on fisheries also exists. It will increase nutrient production in high latitudes (Brander 2010), seasonal increase in growth of rainbow trout (Morgan *et al.* 2001) and reduced cold water mortalities of some aquatic animals (IPCC 2007a).

Table 1: Ecological, direct and socio-economic impacts of climate change on fisheries.

Ecological Impacts	**Direct Impacts**	**Socio-economic Impacts**
Change in yield	Damaged infrastructure	Influx of migrant fishers
Change in species distribution	Damaged gears	Increasing fuel costs
Increased variability of catches	Increased danger at sea	Reduces health due to diseases
Changes in seasonality of production	Loss/gain of navigation routes	Relative profitability of other sectors
	Flooding of fishing communities	Resources available for management
		Funds for adaptation

Source: Daw *et al.* 2009

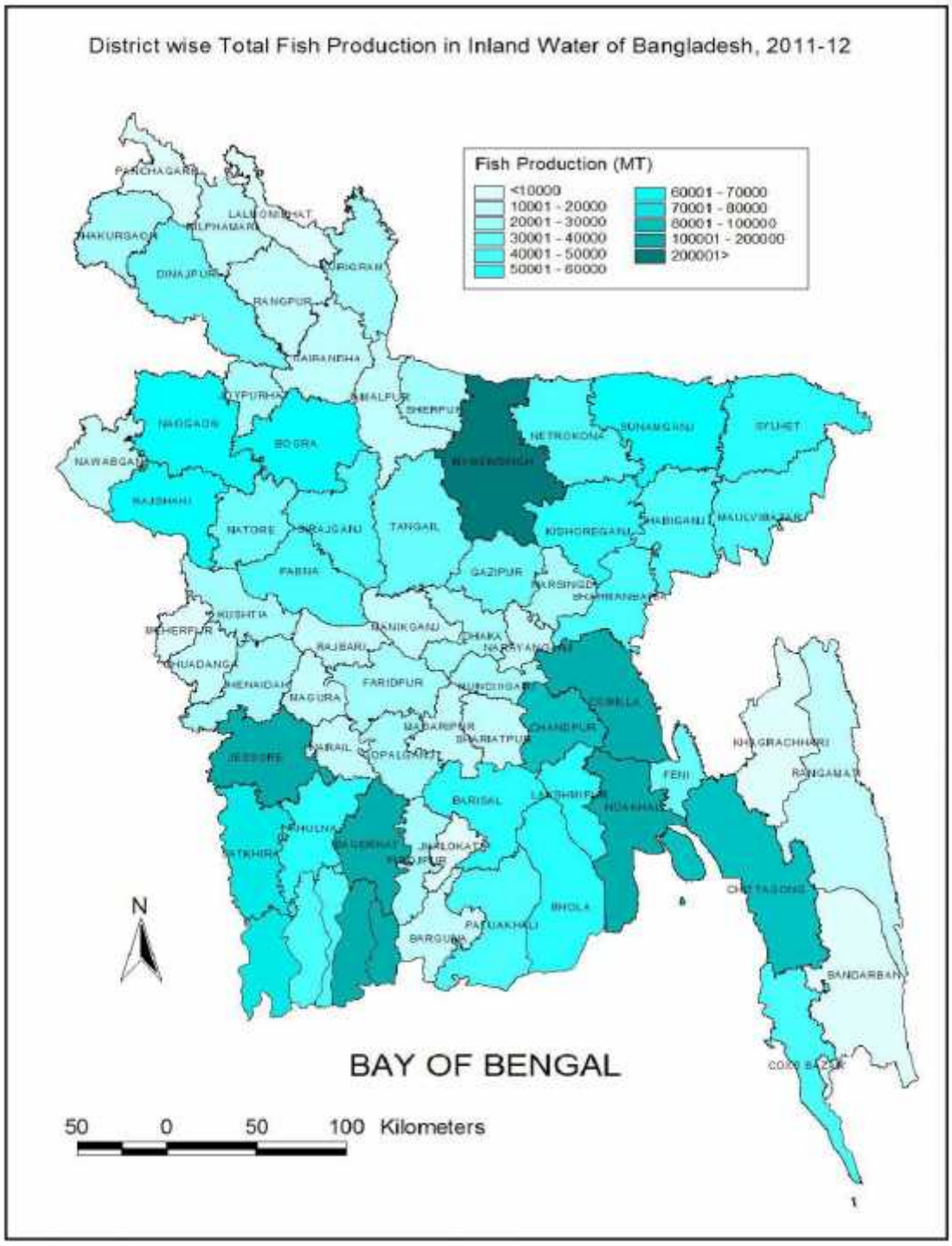
1.5 Fisheries of Bangladesh

Bangladesh has an extensive water resource in the form of ponds, natural depressions (Haors and Beels), lakes, canals, rivers and estuaries covering an area of 4.69 million ha (FRSS 2014). Fisheries sector of Bangladesh contributes about 3.69% to National GDP and almost one-fourth (22.60%) to the Agricultural GDP (FRSS 2015). This sector provides about 60% of the animal protein intake and more than 17.5 million people of the country is directly or indirectly involved in this sector for their livelihoods (FRSS 2015). It is also the country's third largest export earner and the country's export earnings from this sector are 2.01% in 2012-13 (FRSS 2014).

Total production from all sectors of fisheries including inland and marine is 3548115 MT (FRSS 2015). Inland fisheries is divided into two group i.e. culture fisheries and capture fisheries. Annual fish production in inland open water capture fisheries (i.e., river and estuary, the Sundarbans, beel, kaptai lake and floodplain) is 995805 MT which is 28.07% of the total production comprising an water area of 3910053 Ha (FRSS 2015). For inland closed water culture fisheries (i.e., pond, seasonal cultured water body, baor and shrimp/prawn farm), the estimated production is 1956925 MT (55.15% of total production) covering an area of 789341 Ha (FRSS 2015).

However, the resources and the dependency on fisheries (both culture and capture) vary according to the districts. For example, on culture fisheries Mymensingh districts have highest production (301914 MT) but in Bandarban, total culture production is 1435 MT (FRSS 2015). On the other hand, in capture fisheries the highest production has been found in Sunamganj (77363 MT) and the lowest is in Khagrachhari. So fish production in different district vary differently. Also the water area of 64 districts also vary. Figure 1 the showing the variation of fish production in 64 districts of Bangladesh.

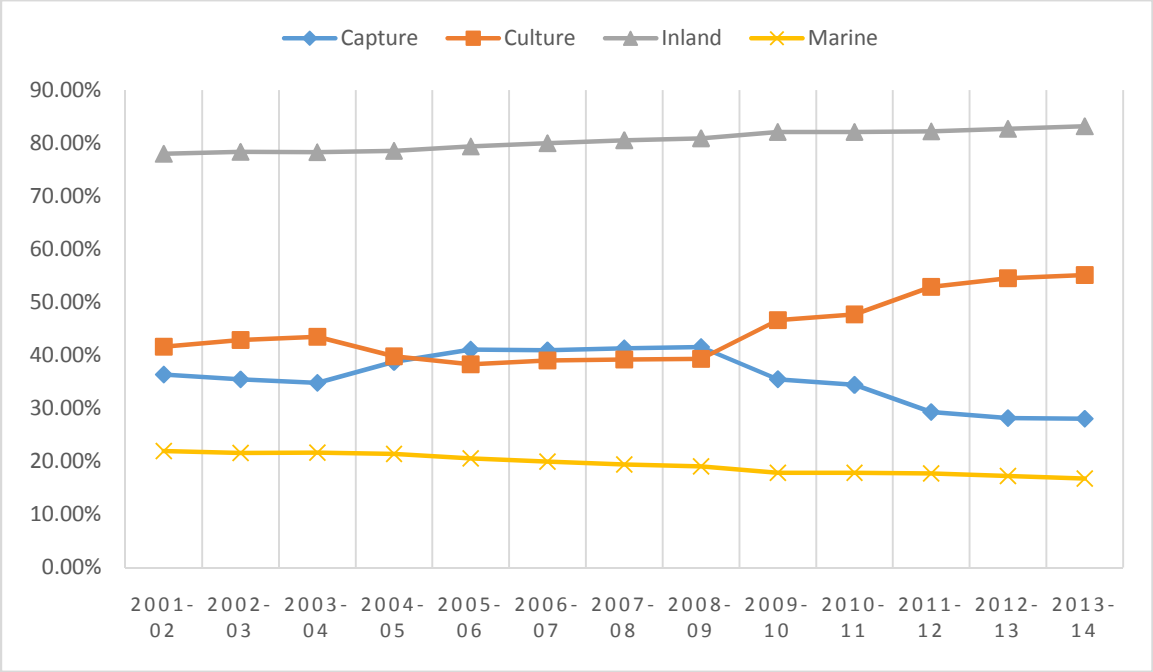
From the percent trend of fish production (Figure 2) of capture, culture, inland and marine fisheries from the year 2001-2002 to 2013-2014, it has been found that, there is a considerable



Source: FRSS 2014.

Figure 1: Variation of production on inland fisheries in 64 districts of Bangladesh.

increase in inland fisheries (from 78.03% to 83.22%) which mainly came from the culture fisheries sector (the production of which increased from 41.61% to 55.15%). But the percent production of both capture fisheries and marine fisheries have decreased from 36.42% to 28.07% and 21.97% to 16.78% (FRSS 2003; FRSS 2015).



Source: FRSS 2003-FRSS 2015

Figure 2: Percent trend of production for capture, culture, inland and marine Fisheries.

1.6 Climate Change in Bangladesh

Over most of the Asian region, in the past century the mean annual temperature has increased (IPCC2014).There has been widespread warming over Bangladesh during both the hot season (March to May) and cool season (December to February) since 1960 (Met Office 2011). By 2100, in Bangladesh the projected temperature increases are in the region of 3 to 3.5°C. During the summer monsoon season (June to September), Bangladesh usually receives more than 70% of its annual rainfall. In 2010 season, the monsoon trough was further south than usual which was the driest monsoon since 1994 in Bangladesh with a

seasonal rainfall total of about 19% less than the long term average (Met Office 2011). The annual mean rainfall proclaims increasing trends but the decadal rain anomalies are above long term average since 1960s (IPCC 2007a). It has been projected that Bangladesh will experience increased precipitation which will be up to 5-10% of which 20% could occur in the north of the country(Met Office 2011) .

The coastal districts of Bangladesh are susceptible to cyclones. It cause major losses of life and property. In the early summer (April and May) and late in the monsoon season (September to November) storms of very high intensity may occur. On 15 November 2007, tropical Cyclone Sidr reached Bangladesh which brought torrential rains and wind speeds of up to 240 km/h(WMO 2008). Cyclone Sidor came after months of repeated floods resulting from one of the worst monsoon seasons that Bangladesh had experienced in years Since 1991, the storm developed near the Andaman Islands in the Bay of Bengal and is regarded as the worst to hit Bangladesh (Gleason 2008).

In Bangladesh, it is projected that 4.8% of people living in unprotected dryland areas could face inundation by a water depth of 30 to 90 cm based on assumptions of a 2°C temperature increase, a 30 cm increase in sea level, an 18% increase in monsoon precipitation, and a 5% increase in monsoon discharge into major rivers (IPCC 2007a). This could increase to 57% of people based on assumptions of a 4°C temperature increase, a 100 cm increase in sea level, a 33% increase in monsoon precipitation, and a 10% increase in monsoon discharge into major rivers. Some areas could face higher levels of inundation (90 to 180 cm) (IPCC 2007a). The flooded area in Bangladesh is projected to increase at least by 23-29% with a global temperature rise of 2°C (IPCC 2007a).

For existing variability and future climate change, Bangladesh is one of the most vulnerable countries to climate change. To maintain economic growth and reduce poverty, the importance of adapting to risks (like annual flooding, lack of water resources in dry season, frequent coastal cyclones and storm surge) is clear (Yu*et al.*2011).

1.7 Impact of Climate Change on Fisheries of Bangladesh

In Bangladesh, 80% of land is flood plains, one-fifth is low lying coastal zones, having 700 rivers and it is densely populated country of which three quarters of people live in rural areas and rely mainly on agriculture and fisheries (Kibria 2015). Climate change is likely to pose threat to water resources and fishery resourcesbecause of temperature increase, enhanced anomalies in the rainfall pattern and frequency and severity of extreme events in Bangladesh. Due to its direct dependence on climate parameters, agriculture and fisheries sector is highly vulnerable(Mustafa 2010). Some projected impacts of climate change on Bangladesh are increased flooding of low lying coastal areas, loss of biodiversity, possible drowning and bleaching of corals in the lone St. Martin's Island, loss and shifting of natural breeding ground of iconic fish-the Gangetic major carps in the Halda River, negative effects on coastal freshwater aquaculture (Kibria 2015).

Fishing communities of Bangladesh has been identified as most vulnerable to potential climate change impacts on its capture fisheries (Figure 2) due to combined effect of predicted warming, the relative importance of fisheries to national economics and diets, and limited societal capacity to adapt to potential impacts and opportunities (Allison *et al.* 2009). Other reasons which made Bangladesh vulnerable to climate variability and change are the low-lying topography, funnel shaped coast (which expose the land to cyclones, tidal surges, seasonal flooding), widespread poverty, large population base and poor institutional development (Ullah and Rahman 2014).

The major vulnerabilities faced by the farming community of southwestern Bangladesh due to climate change were found to be salinity intrusion, scarcity of safe drinking and irrigation water and problems on freshwater fish culture (Ullah and Rahman 2014). Twenty-nine percent (29%) people of coastal area are engaged in open water fishing in Sundarbans (Tusar and Moumita 2013).A study showed that, the livelihood vulnerability of Barguna districts was found significantly higher than the Cox's Bazar's fishing community (Islam *et al.* 2014). Another study in southeast Bangladesh along the river Meghna showed that

households without any flood protection with lower income and less access to productive natural assets face higher exposure risk of flooding and so is vulnerable (Brouwer *et al.* 2007). Hasan *et al.* 2011, found Bhola district vulnerable to climate change and affected by different climatic variables (i.e. cyclone, tidal surge, river bank erosion, salinity, accretion, flood and water logging). These effects cause the people living in the coastal area and depending on the local resources being fall under vulnerable category and their livelihoods are also affected by the impact of climate change. In north-eastern region of Bangladesh (Tanguar haor), production of fisheries is decreasing due to decreased rainfall in these area (Rahaman *et al.* undated). A case study of *Gajnar beel*, Pabna studied the socio-economic effects of climate change on freshwater fisheries affected by the changes of climatic elements and the impacts were so acute in the form of loss of aquatic biodiversity and socio-economic insecurity of the fisherman near the *beel*(Islam 2014). A study in Mymensingh district showed that, various problem occur due to climate change in culture fisheries such as over heat of pond water, bad water quality, disease prevalence, insufficient water in the ponds, reduced feeding activity and lower growth rate hampered the fish growth and survival in culture, nursery and hatchery level (Mustafa 2010).

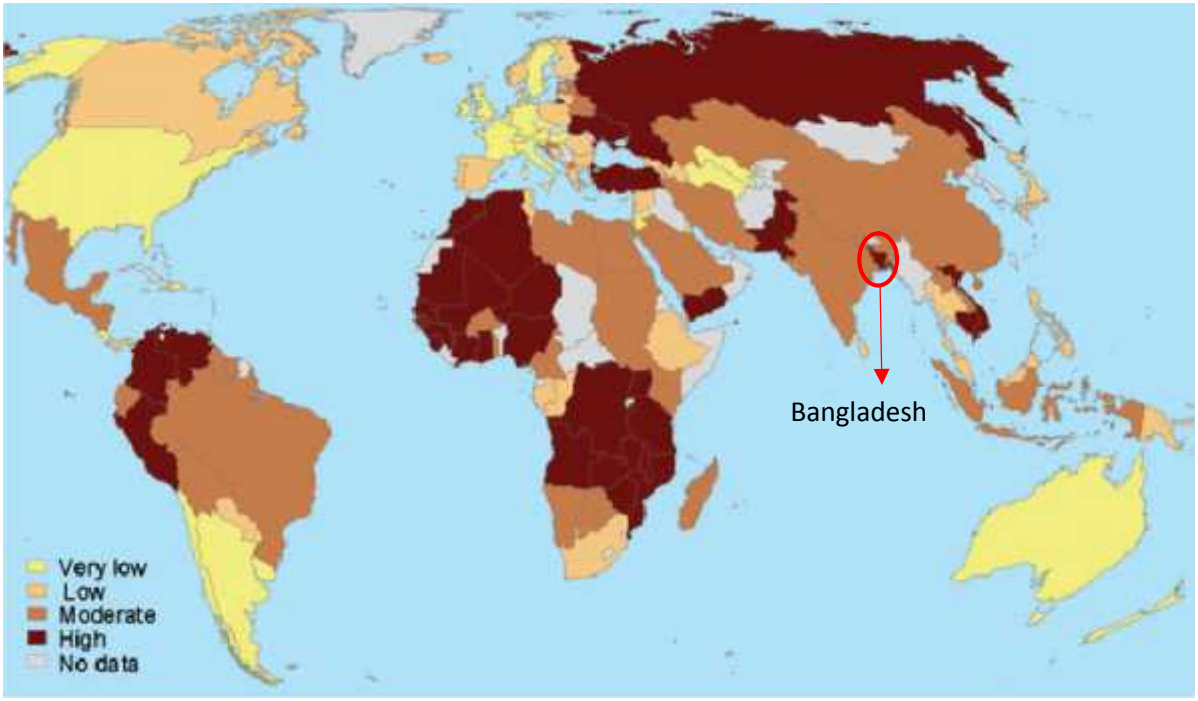


Figure3: Vulnerability of the national economics to the impact of climate change in Fisheries (Allison *et al.* 2009).

Good rainfall and favorable temperature is very important for successful fish breeding and nursery. So high temperature and less rain restrict the breeding and nursery of fish. From a study on the impact of climate change and variability on fisher livelihood of coastal communities on Bhola district found that, as a result of climate change, Bhola is vulnerable and affected by different disasters like cyclone, tidal surge, river bank erosion, salinity, accretion, flood, water logging etc. (Hasan *et al.* 2011). The people living in the coastal area and depending on the native resources are also vulnerable and their livelihoods are also affected by the impacts of climate change on fishery.

To summarize, most of the climatic vulnerability assessment have focused on food security (Fraser, 2007; Tubiello *et al.* 2007; Antwi-Agyei *et al.* 2012) and agricultural production (Fischer *et al.* 2005; Parry *et al.* 2005b; Schmidhuber and Tubiello, 2007; Antwi-Agyei *et al.* 2012). On the other hand, on fisheries sector trends and fluctuations in fish abundance and distribution to climate change have focused (Cushing, 1982; Glantz and Feingold, 1992; Cheung et al. 2009; Brander, 2010; Drinkwater et al. 2010). A number of studies have investigated climate change impact on the vulnerability and adaptive capacity of fisheries and dependent communities at macro scale (e.g., national)(McClanahan *et al.* 2008; Allison *et al.* 2009). But for specific findings applicable to the local community scale, micro-scale study is necessary. Mapping of drought risk in western part of Bangladesh has been conducted by Shahid and Behrawan(2008). Some studies had focused on forest and water resource vulnerability to climate change in Bangladesh (Ahmed *et al.* 1999; Alam 1999). Fish resources vulnerability and adaptation to climate change in Bangladesh was studied in 1999 (Ali 1999). Community level vulnerability and adaptation to climate change in some parts of Bangladesh has been studied (Brouwer *et al.* 2007; Ullah and Rahman 2014; Islam *et al.* 2014; Ahmed and Diana 2015). But district level vulnerability for 64 districts of Bangladesh has not studied. As fisheries of Bangladesh is impacted by climate variability and change, and there has been limited research about this topic, so vulnerability of fisheries to climate change needed to be studied. This study has provided information on the sub-national areas in respect of fisheries resources (District level) most vulnerable to climate change impact in Bangladesh.

1.8 Aim and Objectives of this study

The aimof this study is to determine the level of vulnerability of fisheries at different districts of Bangladesh due to climate variability and change. The specific objectives are-

- to determinethe vulnerability of culture fisheries to the impact of climate variability and change in 64 districts of Bangladesh;
- to determine the vulnerability of capture fisheries to the impact of climate variability and change in 64 districts of Bangladesh; and
- to determine the vulnerability of overall fisheries (culture and capture) to the impact of climate variability and change in 64 districts of Bangladesh.

Chapter 2: Research Design and Methodology

This chapter has described the design and methodology of this research which has started from the selection of indicators for exposure, sensitivity and adaptive capacity of culture, capture and overall fisheries. The next step is the collection of data and finally the analysis of data using composite index approach.

2.1 Selection of Indicators for Culture, Capture and Overall FisheriesSector

Vulnerability is the combined effect of exposure, sensitivity and adaptive capacity (IPCC 2014). So for determining vulnerability, indicators of exposure, sensitivity and adaptive capacity play a very important role. Moreover, as this study has used by district data of all indicators, data availability is another important issue. So selection of indicator in fisheries context is important for this study as there was many scientific and emotional considerations. The detailed cause of indicator selection has given below.

2.1.1 Exposure

As mentioned earlier (section 1.3) that exposure is the nature and degree to which a system is exposed to significant climate variations (IPCC 2007b). Fisheries is influenced by many climate variables through a range of direct and indirect pathways (Allison *et al.* 2009). Changes in air and water temperatures, precipitation, salinity, ocean circulation and mixing, river flow, nutrient levels, sea and lake levels, storm frequency and intensity, and flooding are the key variables (Barange 2002; Stenseth *et al.* 2003; Brander 2007). Changes in the abundance and distribution of exploited species and assemblages (Perry *et al.* 2005; Lehodey *et al.* 2006; Dulvy *et al.* 2008) and increases in the frequency and severity of extreme events, such as floods and storms, which affect fishing operations and infrastructure are the known direct effect of climate change (Brooks *et al.* 2005).

Selecting an indicator for exposure to climate change for whole Bangladesh is not easy. For example, for the coastal regions the community exposure to climate shocks and stresses are floods, cyclones, land erosion, sea level changes, variation in temperature, rainfall etc. (Islam *et al.* 2014) and sea level change is the most important exposure for coastal regions but there is no equivalent for inland waters (Allison *et al.* 2009).In Bangladesh, floods are more frequent than any other disaster that affect people. In 1998 about 70% of the country area was inundated due to extreme floods(IPCC 2007b). Climate change which is the result of global warming has made the situation worse especially for Bangladesh as vast coastal areas stand highly vulnerable to floods and other natural disasters due to steady rise of sea level. So flood could be an important exposure indicator to climate change. But by district record of flood data has not found and that's why flood has not taken as an exposure indictor.The north and north-western parts of Bangladesh are most vulnerable to droughts. But because of unavailability of by district drought data, and as this study used variation of rainfall as an exposure indicator, drought as exposure indicator has not taken. The selector criteria of exposure, sensitivity and adaptive capacity indicators are given below. Table 2 is representing the exposure indicators used in this study.

2.2.1.1 Variation in maximum temperature

The most direct, best understood and most readily available indicator of future climate change is temperature (Scholze *et al.* 2006). Anomalies in the water temperatures results in low commercial fish catch (IPCC 2001). High temperature increases the metabolic activity of fish but sudden change in temperature to higher degree may cause decrease in dissolved oxygen level and increase in bio which will cause death to fish as well as the aquatic organisms. That's why maximum temperature has been selected as an exposure indicator in this study. Moreover, past trend of temperature data is easily available from Bangladesh Meteorological Department.

2.2.1.2 Minimum temperature

A sudden decrease in temperature also creates problem in fisheries. Total area of water decreases in winter season which decrease the fish catch. Moreover, lower temperature decrease metabolic rate and retard growth of fish (FAO 1996). For these reasons, minimum temperature has also been selected as exposure index.

2.2.1.3 Future projected temperature

The predicted rate of future climate change will be more rapid than previous natural changes and the resilience of species and system is being endangered by concurrent pressure, including fishing(Planque *et al.* 2010), loss of biodiversity (including genetic diversity), habitat destruction, pollution, introduced and invasive species and pathogens (Brander 2010). So future change of temperature will negatively expose fisheries sector and this is the reason for which it has been selected as an exposure indicator

2.2.1.4 Variation in rainfall

Another important exposure indicator to climate change is rainfall. It changes the aquatic habitat quality and quantity, ecosystem productivity and the distribution and abundance of aquatic competitors and predators. In general sense, rainfall is definitely good for culture, capture and overall fisheries sector. But changing rainfall pattern that means variation of rainfall impact on inland fisheries and aquaculture. A significant increase of annual and pre-monsoon rainfall in Bangladesh is observed and an increasing trend in heavy precipitation days and decreasing trends in consecutive dry days are observed (Shahid 2011). In northwest Bangladesh, significant changes in most of the extreme rainfall indices are observed (Shahid 2011).Small changes in the mean and standard deviation values can produce relatively large changes in the probability of extreme events (FHS 2006; Groisman *et al.* 1999; Rodrigu 2002). Increased riparian freshwater flow into estuaries and coastal

areas will alter the estuarine ecology which may affect the habitats of various shrimp and fish making inhospitable and inaccessible (Mustafa 2010).

The impacts of additional variable precipitation and extreme weather events are already felt in Bangladesh. Floods of 1998, 200, 2004 and 2007 record the increase of extreme events both frequency and severity (Shahid 2011).Rainfall events have become more erratic in some regions. The erratic rainfall and their associated extreme events may affect ecosystems, productivity of land, agriculture, food security, water availability and quality, health and livelihood of the common people of Bangladesh (Shahid 2011). The timing and the frequency of rainfall is changing which will affect the breeding season and capacity of fishes. So rainfall variation affect negatively in culture, capture and overall fisheries sectors. Thus rainfall is also an important indicator to climate change and past trend data of rainfall is available in BMD.

2.2.1.5 Future projected precipitation

Bangladesh is one of the most vulnerable countries of the world to climate change as the country has very least capacity to address the devastating impacts. According to Iskander *et al.* (2014) Bangladesh will experience 5% to 6% increase of rainfall by 2030. Recent studies indicate an increase in mean and extreme precipitation over Bangladesh and precipitation extremes, either excess or deficit, can be hazardous to human health, societal infrastructure, and livestock(Met Office 2011). So future variation of precipitation will also negatively impact culture, capture and overall fisheries sector.

2.2.1.6 Sea level rise

Sea level change is one of the main factors in stimulating coastal change. The level of sea is not constant, it is always rising and falling.Countries with heavy concentrations of population and economic activity in coastal regionspossess a particular threat by Sea level rise (SLR) (Dasgupta *et al.* 2007).Sea level rise have detrimental effect on coastal aquaculture especially for prawn farming (Ahmed and Diana 2015) in Bangladesh. Sea level rise accelerate coastal erosion and waterlogged condition. It has affected the Sundarbans

mangrove forest which is an important feeding, breeding and nursery ground for prawn as well as many fish species. According to the ministry of Environment and Forest (2005), in Bangladesh, by 2100 there will be a rise of sea level of about 88cm. So the coastal districts of Bangladesh will dawn in future. That's why sea level rise is an important exposure indicator for coastal districts. According to (World Bank 2000), by 2020, 2050 and 2100 sea level will rise 0.10, 0..25 and 1m which will affect 2%, 4% and 17.5% respectively. With a 1 m rise in sea level, 2,500 km^2 of mangroves in Asia are likely to be lost; Bangladesh would be worst affected by the sea level rise in terms of loss of land (IPCC 2007b). Another important factor that will be affected is the surface and groundwater salinity distribution and reduce freshwater habitat. Salinity intrusion will severally impact on culture, capture and thus overall fisheries sector. Pond based aquaculture in coastal area will be affected by sea level rise through submerging the ponds.Moreover an increasing trend of salinity has been found in the southwestern coastal regions of Bangladesh (Ullah and Rahman 2014).

2.2.1.7 Storm surge

Most of the damage occur during a cyclone is done by the storm surge, which sometimes wash over the entire coastal lands. It wash away the whole aquaculture area, destruct the dams and release all culture species in the coastal areas. So for coastal districts for fisheries, storm surge is a big issue that's why it has been selected as an exposure indicator. An assessment of surges in the past 100 years found that major events were confined to a limited number of regions, with many events occurring in the Bay of Bengal,particularly Bangladesh(Nicholls 2003). So fisheries (both culture and capture) of the coastal districts of Bangladesh are negatively affected by storm surge.

2.2.1.8 Cyclone

A tropical storm or atmospheric turbulence involving circular motion of winds called cyclone occurs in Bangladesh as a natural hazard. Most cyclones occur during the peak seasons of aquaculture. A huge volume of debris, trash and dead organisms is washed into aquaculture farm by cyclones. Moreover, many structural damage also occur during cyclone

which cause vulnerability to coastal people especially to the fishers. So cyclone is an important exposure indicator of climate change.Between 1877 and 1995, 154 cyclones hit Bangladesh of which 43 were severe (Dasgupta *et al.* 2014). Cyclones and tidal surges in 1991, 1998, 2000, 2004 and 2007 record the increase of extreme events both in frequency and severity. Super cyclone Sidr in 2007 exceeded previous records of its coverage and wind velocity which killed over 10,000 people and destructed houses of 30 million(Shahid 2011). In 1980 to 2000, a total of more than 250,000 deaths were associated with tropical cyclones, of which 60% occurred in Bangladesh (this is less than the 300,000 killed in Bangladesh in 1970 by a single cyclone) (IPCC 2007b). Estimates of future tropical cyclone damages in Bangladesh due to climate change are highly uncertain. Capture fisheries is highly vulnerable to such damages, however, due to the country's topography and limited resources for adaptation (Met Office 2011).

2.2.1.9 Land erosion

Climatic changes are likely to increase major land degradation problems such as erosion and salinization. In Asia, Coastal erosion led to loss of lands at rates dependent on varying regional tectonic activities, sediment supply and sea-level rise (Sin 2000). Food insecurity and loss of livelihood are likely to be further exacerbated by the loss of cultivated land and nursery areas for fisheries by inundation and coastal erosion in low-lying areas of the tropical Asia. Increased rainfall intensity is likely to exacerbate soil erosion problems and pollution of streams during forestry operations (IPCC 2001). Coastal erosion of the major deltas will be caused by sea-level rise, intensifying extreme events (e.g., storm surge) due to climate change and excessive pumping of groundwater for irrigation and reservoir construction upstream. The poorer segments of society live closer to the river, and therefore face a higher risk of erosion and are thus more vulnerable. Conservation of mangroves is considered as effective natural protection against storm surges, coastal erosion and strong wave actions.

Table 2: Indicators of exposure for culture, capture and overall fisheries sector.

Climate shocks and stresses	**Culture**	**Capture**	**Overall fisheries**	**References**
Variation in past maximum temperature (°C)	✓	✓	✓	Bangladesh Meteorological Department(2015)
Variation in past minimum temperature (°C)	✓	✓	✓	Bangladesh Meteorological Department(2015)
Future temperature projection (°C)	✓	✓	✓	Met Office (2011)
Variation in past rainfall (mm)	✓	✓	✓	Bangladesh Meteorological Department(2015)
Future precipitation projection (% change)	✓	✓	✓	Met Office (2011)
Past sea level change (mm/year)	✓	✓	✓	Yu *et. al.*(2011)
Past land erosion	✗	✓	✓	CEGIS (Center for Environmental and Geographic Information Service) (2015)
Storm Surge	✓	✓	✓	CEGIS (2015)
Cyclone	✗	✓	✓	CEGIS (2015)

2.1.2 Sensitivity

The intrinsic degree to which biophysical, social and economic conditions are likely to be influenced by extrinsic stresses or hazards is called sensitivity (IPCC 2001). So in this context sensitivity is the nature and degree to which fisheries is exposed to significant climate variations (IPCC 2001). Sensitivity indicators characterize the first-order effects of stresses (IPCC 2001). Sensitivity is represented by the fisheries dependence and the importance of fisheries to national economics and food security (Allison *et al.* 2009). Here fisheries dependence means fisheries landings, employment from fisheries, export income

and dietary protein percentage for fish (Allison *et al.* 2009). So if a district is highly dependent on fisheries for employment, income and dietary protein, it will more likely to be impacted by climate related change (Allison *et al.* 2009).

The fisheries dependence of national economies was represented using a composite indicator comprised of fisheries production (landings), and the contributions of fisheries to employment, export income and dietary protein. This assumes that countries with higher landings and higher contributions of fisheries to employment, export income and dietary protein are more likely to be impacted (positively or negatively) by warming-related changes in the whole fishery production systems of that nation. A composite index of sensitivity was calculated as an unweighted average of the indices of production, economic dependence and nutritional dependence. Fisheries production could be represented using either capture fisheries landings (i.e. excluding discards) or catch value. Sensitivity indicators used in this study is given in Table 3.

Table 3: Indicators of sensitivity for Culture, Capture and overall Fisheries.

Fisheries Sectors	**Sensitivity Indicators**	**Sources of data**
Culture Sensitivity	• Fish production from culture fisheries • Total water area used in culture	• FRSS (2003-2015) • CEGIS (2015)
Capture Sensitivity	• Fish production from capture fisheries • Total water area used in capture	
Fisheries Sensitivity	• Fish production in overall fisheries • Total water area used in fisheries	

2.1.3 Adaptive capacity

Adaptive capacity is the ability of a system to adjust to climate change (including climate variability and extremes), to moderate the potential damage from it, to take advantage of its opportunities, or to cope with its consequences (IPCC 2001). Development of human, institutional and financial management capacities entitled effective adaptation. Appropriate infrastructure i.e. House, tube well, paved road, school, college etc. and technology i.e. electricity etc. creates livelihoods and reduces vulnerability of poor people (Sperling 2003). Good adaptation practices reduce vulnerability of expected climate change. Improved resource management and use of technology leads to effective management.

Adaptive capacity can be influenced by infrastructure, community structure and social groups, household structure and composition, knowledge, social capital (such as kinship networks and social support institutions), political influence, power relations, governance structures, managerial ability, and ability or inability to access livelihood assets, especially financial, technological, and information resources (Watts and Bohle 1993; Adams and Mortimore 1997; David 1998; Adger 1999; Handmer *et al.* 1999; Wisner *et al.* 2014; Haddad 2005; Ford *et al.* 2006; Smit and Wandel 2006; Tol and Yohe 2007; Vincent 2007; Paavola 2008; Sallu *et al.* 2010). Table 4 is describing the adaptive capacity indicators used in this study.

2.2.3.1 Less poverty

Among the factors imposing limitations to adaptive capacity, the most significant is persistent poverty, which signifies absence of the resources necessary for adapting to climate change (Sperling 2003). Poor people are mostly affected by climate change (IFAD 2008). Poor people, communities or nations do not have enough resources (social, financial, natural, physical and human capital), hence low adaptive capacity. That's why, poverty level

has been selected as an adaptive capacity indicator.More poverty means less adaptive capacity and vice versa.

2.2.3.2 Gross district product

Financial resources that people use to achieve their livelihood objectives are the financial assets e. g., per capita income (Fang*et al.* 2014), Gross District product etc. Human assets includes knowledge, skills and health including education levels, fishing skills and physical ability to work (Goodwin 2003). For the effective use of the other four types of assets human assets is essential (Kwon 20009). Households with lower income and less access to productive natural resources face higher exposure (Brouwer *et al.* 2007).

2.2.3.3 Literacy rate

Literacy is traditionally understand as the ability of a person to read and write. Education is the basic need of a person. Large percentage of literacy rate means higher adaptive capacity that means higher ability to adapt in changing climatic conditions (Adams and Mortimore 1997; Brooks *et al.*2005). So literacy rate is an important indicator of adaptive capacity.

2.2.3.4 Electricity coverage

Electricity coverage is the percent area of a certain district that have electricity connection. Electricity coverage is used as an indicator of adaptive capacity because it increase adaptation in adverse climatic conditions. For aquaculture, electricity is an important part for good management.

2.2.3.5 Housing structure

The principle function of a house is to provide protection from natural calamities. It provides not only shelter but also privacy, safety and reasonable protection of our mental and physical

health. So housing structure is an important adaptive capacity in changing climatic conditions.

2.2.3.6 Monthly expenditure

Monthly expenditure is the amount of money that people spent for living in one month. High monthly expenditure denotes higher stability to adverse condition that is higher adaptive capacity (Alberini *et al.* 2005). For these reasons, monthly expenditure has been selected as an adaptive capacity indicator.

2.2.3.7 Length of paved pond

Physical infrastructure and tools or equipment used to support livelihoods form physical capital. These includes both fisheries resources and non-fisheries resources like roads, dams, schools, water supply systems etc. Paved road denotes the transportation efficiency that means higher adaptive capacity.

2.2.3.8 Total number of primary school, secondary school and tube well

Higher number of primary school, secondary school and tube well means higher capacity of adaptation.

Table 4: Indicators of adaptive capacity for Culture, Capture and Overall Fisheriessector.

Indicators of adaptive capacity	**Explanation of indicators**	**Sources of data**
Less Poverty	Percent poverty rate (upper poverty line)	World Bank (2014)
GDP	Gross of district product	Khondker and Mahzab (2015)
Literacy	Adult literacy of population for ages 7 years or above (year)	BBS (2013)
Electricity	Percentage coverage of Electricity	CEGIS(2015)
Housing structure		CEGIS(2015)
Expenditure	Per capita monthly consumption expenditure	Khondker and Mahzab (2015)
Road	Length of paved road (km)	Khondker and Mahzab 92015)
Primary School	Total number of primary school	Khondker and Mahzab (2015)
Secondary School	Total number of secondary school	Khondker and Mahzab (2015)
Tube well	Total number of tube well	Khondker and Mahzab (2015)

2.2 Collection of Data

2.2.1 Collection of Exposure Data

Data of maximum and minimum temperature and daily rainfall of 34 stations from whole Bangladesh were collected from Bangladesh Meteorological Department (BMD), Agargaon, Dhaka. The time period of data collected for each station by BMD is given in Table 5.

Table 5: Time periods of maximum temperature and minimum temperature collected for this study for each stations of BMD.

Divisions	**Districts**	**Time periods**
Dhaka	Dhaka	1975 to 2014
	Faridpur	1975 to 2014
	Madaripur	1977 to 2014
	Mymensingh	1975 to 2014
	Tangail	1987 to 2014
Chittagong	Ambagan	1999 to 2014
	Chandpur	1975 to 2014
	Chittagong	1975 to 2014
	Comilla	1975 to 2014
	Cox's Bazar	1975 to 2014
	Feni	1975 to 2014
	Hatiya	1975 to 2014
	Kutubdia	1985 to 2014
	Majid Court	1975 to 2014
	Rangamati	1975 to 2014
	Sandwip	1976 to 2014
	Sitakunda	1977 to 2014
	Teknaf	1977 to 2014
Rajshahi	Bogra	1975 to 2014
	Ishwardi	1975 to 2014
	Rajshahi	1975 to 2014
Rangpur	Dinajpur	1981 to 2014
	Rangpur	1975 to 2014
	Sydpur	1991 to 2014
Khulna	Chuadanga	1989 to 2014
	Jessore	1975 to 2014
	Khulna	1976 to 2014
	Mongla	1989 to 2014
	Satkhira	1975 to 2014
Barisal	Barisal	1975 to 2014
	Bhola	1975 to 2014
	Khepupara	1975 to 2014
	Patuakhali	1975 to 2014
Sylhet	Srimangal	1975 to 2014
	Sylhet	1975 to 2014

As there are only 34 meteorological stations in whole Bangladesh to cover the climatic data of 64 districts, the climatic data of other districts were adjusted by using the nearby station's data. The adjusted stations of other districts are given in Table 6.

Table 6: Stations used to adjust other districts which does not have meteorological station.

Districts	**Adjusted station**	**Districts**	**Adjusted station**
Gazipur	Dhaka	Brahmanbaria	Comilla
Gopalgonj	Dhaka	Lakshmipur	Majid court
Jamalpur	Bogra	Noakhali	Majid court
Kishorgonj	Mymensingh	Khagrachhari	Sitakunda
Manikgonj	Dhaka	Chittagong	Sitakunda + Chittagong + Kutubdia
Munshigonj	Dhaka	Bandarban	Cox's Bazar
Narayanganj	Dhaka	Cox's Bazar	Cox's Bazar + Teknaf
Narsingdi	Dhaka	Kushtia	Ishwardi
Netrakona	Mymensingh	Meherpur	Chuadanga
Rajbari	Faridpur	Jhenaidah	Chuadanga + Jessore
Shariatpur	Madaripur + Chandpur	Narail	Jessore
Sherpur	Mymensingh	Bagerhat	Mongla
Pirojpur	Barisal	Joypurhat	Bogra
Jhalokati	Patuakhali	Naogaon	Rajshahi
Barguna	Khepupara	Nawabganj	Rajshahi
Panchagarh	Sydpur	Natore	Ishwardi
Thakurgaon	Dinajpur	Pabna	Ishwardi
Nilphamari	Sydpur	Sirajganj	Bogra + Ishwardi
Lalmonirhat	Rangpur	Moulvibazar	Srimangal
Kurigram	Rangpur	Sunamganj	Sylhet
Gaibandha	Rangpur + Bogra	Habiganj	Srimangal

Future climatic projection of temperature and precipitation was collected from the report of the Met Office Hadley Centre(Met Office 2011), which shows the percentage change in average annual temperature and precipitation by 2100 from 1960-1990 baseline climate averaged over 21 CMIP3 models. The percentages were given in range which was averaged for analyzing in SPSS.

Past sea level change data was collected from the excerpt of Climate Change Risks and Food Security in Bangladesh published by Earthscan(Yu *et al.* 2011). It is the estimated trends in water level of different stations along the coastline which was published by BWDB (Bangladesh Water Development Board) and CEGIS in 2006 and the data is statistically significant to $p<0.05$. The values were adjusted for various districts which is given in Table 7.

Table 7: Past sea level change adjusted for various districts from various stations.

Districts	**Stations**
Khulna	Hiron point
Patuakhali	Khepupara + Galachipa + Dasmunia
Bhola	Kyoyaghat + Daulatkhan
Lakshmipur	Nilkamal
Noakhali	Companyganj
Chittagong	Chittagong + Dohazari
Cox's Bazar	Lemsikhali + Cox's Bazar

It is very common that the districts adjacent to the bank of big river like Padma, Meghna and Jamuna are exposed to land erosion. Land erosion record beside the river Jamuna, Ganges and Padma were collected from the official website of CEGIS. Coastal districts like Chandpur, Lakshmipur, Noakhali, Barisal, Bhola and Patuakhali are exposed to erosion because of the presence of Bay of Bengal. Other coastal districts like Satkhira, Khulna and Bagerhat is free of erosion because of the protection by the largest mangrove forest Sundarbans. The other two coastal districts Chittagong and Cox's Bazar is protected from

erosion because of beach area. Erosion data were collected in yes/no basis. District which are exposed to erosion was given yes mark (which carry a value of 1) and which doesn't have were given no mark (value 0). Cyclone and storm surge data were adjusted by expert opinion that the coastal districts are affected to these major climatic events.

2.2.2 Collection of Sensitivity Data

Fisheries Resource Survey System (FRSS) published by Department of Fisheries (DoF), Bangladesh was used to collect the data of fish production. For culture fish production data inland open water sectors like River and Estuary, Sundarbans, Beel, Kaptai Lake and Floodplain productions were united together. Capture fish production from 2003 to 2015 was used for this study. On the other hand, fish production from pond, seasonal cultured water body, baor and shrimp/prawn farm were combined together for culture fisheries production. Overall inland fisheries production data were also collected from these records. Those data were first sorted in separate excel file according to capture, culture and overall inland fisheries production for each year from 2003 to 2015.

By district water area as fish habitat for overall fisheries were collected from CEGIS. However, water area of three districts namely Barguna, Bhola and Pirojpur were missing in CEGIS data which was collected further from the district profile of BBS published in 2011. On the other hand, area which is used for culture fish production were collected from FRSS data book. Pond, seasonal culture water body, baor and shrimp/prawn culture area from the year 2003 to 2015 was used in this study. For capture fisheries, area of beel and Kaptai Lake were collected from FRSS. But area of major rivers, floodplain and the Sundarbans water area by district were collected from CEGIS data division.

2.2.3 Collection of Adaptive Capacity Data

Poverty data which was used as percent poor (upper poverty line) was collected from Zila level povmap estimates, 2010 published by the World Bank(World Bank 2010).Per capita

Gross District Product at current price in 2010-11, per capita monthly consumption expenditure, length of paved road by district, Number of Primary school, Secondary school and Tube well were collected from background study paper for Preparation of the Seventh Five-Year Plan named Lagging District Development(Khondker and Mahzab Undated). By district electricity coverage and housing structure data were collected from CEGIS. Adult literacy rate of population for all ages by district data were collected from Bangladesh Bureau of Statistics(BBS), Agargaon, Dhaka(BBS 2013). Literacy rate for persons aged 7 years or above of 2001 and 2011 were used in this study.

2.3 Analysis of Data

This study analyzed data in various stage using various methods and computer software. The detailed process of data analysis has been given in the sections below.

2.3.1 Composite Index Approach

A composite vulnerability index is a type of measurement system which computes vulnerability indices by aggregating data for a set of indicators. The calculation of composite vulnerability index consist of four steps: selecting indicators, standardizing indicators, calculating sub-indices and finally calculating vulnerability. An indicator represents a characteristic or a parameter of a system (Cutter *et al.* 2008) and it is an empirical, observable measure of a concept (Siniscalco and Auriat 2005). The composite index approach can help to identify indicators or determinants for targeting interventions and programs (Eakin and Bojórquez-Tapia 2008; Czúcz *et al.* 2009).

2.3.2Excel Analysis of Data

Quantitative data collected from various organizations and reports were inputted in MS Excel worksheet (Version 2013) for easy calculation and finally the Predictive Analytical Software (formally known as Scientific Package for Social Science-SPSS) for calculating

exposure, sensitivity, adaptive capacity and finally the vulnerability of culture, capture and overall inland fisheries sector.

2.3.2.1 Calculation of temperature and rainfall data

For calculation, temperature of each stations were separated in separate excel worksheet (Microsoft excel worksheet 2013). Then for all stations and for all months (30 days), the daily records of temperature were calculated by standard deviation. The formula used is-

$$STDEV.P = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \bar{x})^2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where,

STDVE.P = Standard deviation of population

N = Number of population; x_i = Observed value

$\bar{x}$ = mean value of the observation.

And then the results were averaged using the formula below.

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_1 + x_2 + x_3 \ldots\ldots\ldots\ldots\ldots + x_n \ldots\ldots\ldots\ldots\ldots (2)$$

Where,

$\bar{x}$ = average or mean value of observation

n = Number of observation

$x_1, x_2, \ldots, x_n$ = Observations

One final result for each station was collected from the data sheet which was the average of all standard deviations. Finally those dataset were inputted in the SPSS software for final calculation.

2.3.2.2 Other calculations of data

To produce by district value of production for culture, capture and overall inland fisheries, standard deviation of population (Formula 1) was done to the production trend from the FRSS yearbook 2001-2002 to 2013-2014 in separate excel worksheet (version 2013). Finally they were inputted in SPSS.

2.3.3 Calculating Vulnerability of Culture Fisheries

For calculating vulnerability of culture fisheries Partial analytical Software (SPSS-version 20) was used. Table 8 is the name of the districts and their numbers which was used in SPSS software during calculation. The order of the districts were given according to the author's choice.

Table 8: District names and their numbers used in SPSS software.

No	Districts	NO	Districts	No	Districts
1	Dhaka	23	Kushtia	45	Naogaon
2	Faridpur	24	Magura	46	Natore
3	Gazipur	25	Meherpur	47	Pabna
4	Gopalganj	26	Narail	48	Rajshahi
5	Jamalpur	27	Satkhira	49	Sirajganj
6	Kishoreganj	28	Barguna	50	Bandarban
7	Madaripur	29	Barisal	51	Brahmanbaria
8	Manikganj	30	Bhola	52	Chandpur
9	Munshiganj	31	Jhalokati	53	Chittagong
10	Mymensingh	32	Patuakhali	54	Comilla
11	Narayanganj	33	Pirojpur	55	Cox's bazar
12	Narsingdi	34	Dinajpur	56	Feni
13	Netrakona	35	Gaibandha	57	Khagrachhari
14	Rajbari	36	Kurigram	58	Lakshmipur
15	Shariatpur	37	Lalmonirhat	59	Noakhali
16	Sherpur	38	Nilphamari	60	Rangamati
17	Tangail	39	Panchagarh	61	Habiganj
18	Bagerhat	40	Rangpur	62	Moulvibazar
19	Chuadanga	41	Thakurgaon	63	Sunamganj
20	Jessore	42	Bogra	64	Sylhet

21	Jhenaidah	43	Nawabganj		
22	Khulna	44	Joypurhat		

The original value of indicators used for calculating exposure, sensitivity and adaptive capacity of culture fisheries were then inputted in SPSS software. The indicators of exposure, sensitivity and adaptive capacity for vulnerability calculation are given in Table 9.

Table 9: Exposure, Sensitivity and Adaptive Capacity indicators used for the assessment of culture fisheries vulnerability.

Exposure	**Sensitivity**	**Adaptive Capacity**
• Variation of maximum temperature • Variation of minimum temperature • Future projected temperature • Variation of daily rainfall • Future projected precipitation • Sea level rise • Storm Surge	• Fish production from culture fisheries • Total area used for culture fisheries	• Poverty • GDP • Education • Electricity coverage • Housing structure • Expenditure • Paved road • Number of primary school • Number of secondary school • Number of tube-well

All the data of exposure, sensitivity and adaptive capacity were inputted in SPSS.All those variables were then computed by the following formula to get the standardized value of each variable:

$$\text{Index}_{si} = \frac{S_i - S_{min}}{S_{max} - S_{min}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where, $Index_{si}$ = a normalized value of an indicator of vulnerability

S_i = the actual value of an indicator

S_{max} = the maximum value of an indicator

S_{min} = the minimum value of an indicator

A standard value of 0 to 1 was adopted in this analysis where 0 is the lowest value and 1 is the highest value. For inland fish production, as it has been used as an indicator of sensitivity, the more the production is the less it is sensitive. But the formula of standardization gives the reverse result (the highest production give a value of 1and the lowest production gives a value of 0). So for the true result of standardized fish production the following formula has used:

Final fish production = [1 – (Standardized fish production)]

After using this formula, the district with a value of 1 will show the highest sensitivity and one with 0 value will show lowest sensitivity.

The standardized value of the exposure indicators are added together to get the exposure value. Again the exposure value is standardized using formula 3. Same procedure was followed to calculate sensitivity and adaptive capacity value.

Function of exposure and sensitivity are said to be the potential impact of climate change which may be reduced by adaptive capacity (Allison *et al.* 2009) . So the relationship among exposure, sensitivity and adaptive capacity is context-specific (Turner *et al.* 2003). Two types of approach i.e. additive and multiplicative are used to create a composite vulnerability index (Adopted from Allison*et al.* 2009).

V = [(E + S) – AC] … … … … … … (4) (Additive)

or,

V = [(E × S) – AC] … … … … … … (5) (Multiplicative)

Where, V = Vulnerability

E = Exposure; S = Sensitivity

AC = Adaptive Capacity

In this study, additive method of vulnerability has been used to calculate vulnerability of culture, capture and overall fisheries sector. In additive approach, the final vulnerability values depends equally on all three components (i.e. exposure, sensitivity and adaptive capacity) (Hajkowicz 2006).

2.3.4 Calculating Vulnerability of Capture Fisheries

The assessment of the capture fisheries vulnerability was same like the assessment of culture fisheries vulnerability. The only difference was in the use of indicators for exposure and sensitivity. The indicators of adaptive capacity was all the same in culture, capture and overall fisheries. The indicators of exposure, sensitivity and adaptive capacity used for assessing capture fisheries vulnerability is given in Table 10.

Table 10: Indicators of exposure, sensitivity and adaptive capacity used to assess vulnerability of capture fisheries.

Exposure	**Sensitivity**	**Adaptive Capacity**
• Variation of maximum temperature • Variation of minimum temperature • Future projected temperature • Variation of daily rainfall • Future projected precipitation • Sea level rise • Erosion • Storm surge • Cyclone	• Fish production from capture fisheries • Total area of capture fisheries	• Poverty • GDP • Education • Electricity coverage • Housing structure • Expenditure • Paved road • Number of primary school • Number of secondary school • Number of tube-well

2.3.5 Calculating Vulnerability of Fisheries

The assessment of the overall fisheries vulnerability was also same as the assessment of culture and capture fisheries vulnerability. The indicators used for exposure and adaptive capacity was same like exposure of capture fisheries. The difference was in sensitivity indicators. The details description of indicators are given in Table 11.

Table 11: Indicators of exposure, sensitivity and adaptive capacity for assessing vulnerability of fisheries sector.

Exposure	**Sensitivity**	**Adaptive Capacity**
• Variation of maximum temperature • Variation of minimum temperature • Future projected temperature • Variation of daily rainfall • Future projected precipitation • Sea level rise • Erosion • Storm surge • Cyclone	• Fish production from inland fisheries • Total area of inland fisheries	• Poverty • GDP • Education • Electricity coverage • Housing structure • Expenditure • Paved road • Number of primary school • Number of secondary school • Number of tube-well

2.3.5 Mapping of vulnerability

For mapping vulnerability of culture, capture and fisheries sector, the normalized values of exposure, sensitivity and adaptive capacity has been divided into four quartiles. The category used for mapping exposure, sensitivity, adaptive capacity and vulnerability of all sectors, are given in Table 12. Separate by district map of exposure, sensitivity, adaptive capacity and vulnerability has generated for culture, capture and overall fisheries sector. ArcMap 10.3, a geospatial processing program (GIS software) has been used to map vulnerability by district. Vulnerability values were inputted in the administrative boundary of Bangladesh and different colors has given to show the level of vulnerability.

Table 12: Category of exposure, sensitivity, adaptive capacity and vulnerability according to the quartile.

Quartile	**Category**
First quartile	Low
Second quartile	Moderate
Third quartile	High
Fourth quartile	Very high

Chapter 3: Results and Discussion

3.1 Vulnerability of Culture Fisheries

Vulnerability of culture fisheries is the combined effect of exposure, sensitivity and adaptive capacity. For measuring vulnerability of culture fisheries, detailed calculated value of exposure, sensitivity and adaptive capacity are given below.

3.1.1 Exposure

Table 13is showing the values (normalized) of exposure of culture fisheries of 64 districts calculated using the climatic indicators (normalized).When these exposure values were categorized into quartiles (Very high, high, moderate and low), it showed that thirteen (13)districts namely Panchagarh, Thakurgaon, Nilphamari, Lalmonirhat, Dinajpur, Rangpur, Kurigram, Gaibandha, Khulna, Shariatpur, Lakshmipur, Noakhali and Feni are very highly exposed to climate change (see Figure 4 and Table 13). Most of the districts are either in the north Bengal or in coastal areas. Moreover, majority of the districts (43 districts) of Dhaka, Rajshahi, Khulna and Sylhet divisions are in highly exposed category (see Table 13), seven (7) districts fall into the category of moderately exposed and the rest one (1) district Bandarban is in low exposed category. Figure 4 is showing the exposure map of culture fisheries for 64 districts of Bangladesh. District name and their category of exposure level are given in Table 14.

Table 13: District level values of exposure to climate change on culture fisheries sector in Bangladesh[1].

Districts	***MaxT***	***MinT***	***FPT***	***VDR***	***FPP***	***SLR***	***SS***	***Exposure***
Dhaka	0.53	0.81	1	0.45	0	0	0	**0.59**
Faridpur	0.56	0.72	1	0.37	0	0	0	**0.55**
Gazipur	0.53	0.81	1	0.45	0	0	0	**0.59**
Gopalganj	0.47	0.66	1	0.40	0	0	0	**0.50**
Jamalpur	0.75	0.61	1	0.31	0	0	0	**0.55**
Kishoreganj	0.69	0.68	1	0.44	0	0	0	**0.60**
Madaripur	0.47	0.66	1	0.40	0	0	0	**0.50**
Manikganj	0.53	0.81	1	0.45	0	0	0	**0.59**
Munshiganj	0.53	0.81	1	0.45	0	0	0	**0.59**
Mymensingh	0.69	0.68	1	0.44	0	0	0	**0.60**
Narayanganj	0.53	0.81	1	0.45	0	0	0	**0.59**
Narsingdi	0.53	0.81	1	0.45	0	0	0	**0.59**
Netrakona	0.69	0.68	1	0.44	0	0	0	**0.60**
Rajbari	0.56	0.72	1	0.37	0	0	0	**0.55**
Shariatpur	0.42	0.51	1	0.41	0	0	1	**0.78**
Sherpur	0.69	0.68	1	0.44	0	0	0	**0.60**
Tangail	0.71	0.67	1	0.37	0	0	0	**0.58**
Bagerhat	0.51	0.40	0	0.32	0	0	1	**0.41**
Chuadanga	0.77	0.89	1	0.19	0	0	0	**0.62**
Jessore	0.65	0.93	1	0.27	0	0	0	**0.61**
Jhenaidah	0.71	0.91	1	0.23	0	0	0	**0.61**
Khulna	0.57	0.85	0	0.33	0	1	1	**0.91**
Kushtia	0.77	0.91	1	0.24	0	0	0	**0.64**
Magura	0.65	0.93	1	0.27	0	0	0	**0.61**
Meherpur	0.77	0.89	1	0.19	0	0	0	**0.62**
Narail	0.65	0.93	1	0.27	0	0	0	**0.61**
Satkhira	0.51	1.00	0	0.30	0	0	1	**0.60**
Barguna	0.11	0.72	0	0.72	0	0	1	**0.51**
Barisal	0.38	0.76	0.5	0.00	0	0	1	**0.54**
Bhola	0.28	0.65	0	0.46	0	0.77	1	**0.71**
Jhalokati	0.31	0.52	0	0.62	0	0	1	**0.48**
Patuakhali	0.31	0.52	0	0.62	0	0.45	1	**0.63**
Pirojpur	0.38	0.76	0	0.00	0	0	1	**0.38**
Dinajpur	0.88	0.58	1	0.49	1	0	0	**0.98**
Gaibandha	0.78	0.59	1	0.44	1	0	0	**0.93**
Kurigram	0.82	0.58	1	0.56	1	0	0	**0.98**
Lalmonirhat	0.82	0.58	1	0.56	1	0	0	**0.98**
Nilphamari	0.94	0.52	1	0.55	1	0	0	***1.00***

Panchagarh	0.94	0.52	1	0.55	1	0	0	***1.00***
Rangpur	0.82	0.58	1	0.56	1	0	0	**0.98**
Thakurgaon	0.88	0.58	1	0.49	1	0	0	**0.98**
Bogra	0.75	0.61	1	0.31	0	0	0	**0.55**
C. Nawabganj	0.83	0.89	1	0.21	0	0	0	**0.64**
Joypurhat	0.75	0.61	1	0.31	0	0	0	**0.55**
Naogaon	0.83	0.89	1	0.21	0	0	0	**0.64**
Natore	0.77	0.91	1	0.24	0	0	0	**0.64**
Pabna	0.77	0.91	1	0.24	0	0	0	**0.64**
Rajshahi	0.83	0.89	1	0.21	0	0	0	**0.64**
Sirajganj	0.76	0.76	1	0.28	0	0	0	**0.59**
Bandarban	0.08	0.00	0	0.94	0	0	0	***0.00***
Brahmanbaria	0.45	0.60	1	0.44	0	0	0	**0.49**
Chandpur	0.37	0.37	1	0.43	0	0	1	**0.72**
Chittagong	0.16	0.33	0	0.85	0	0.46	1	**0.59**
Comilla	0.45	0.60	1	0.44	0	0	0	**0.49**
Cox's Bazar	0.00	0.05	0	0.94	0	0.31	1	**0.43**
Feni	0.54	0.61	1	0.74	0	0	1	**0.96**
Khagrachhari	0.35	0.74	0	0.90	1	0	0	**0.66**
Lakshmipur	0.42	0.51	0.5	0.81	0	0.41	1	**0.88**
Noakhali	0.42	0.51	0.5	0.81	0	0.7	1	**0.97**
Rangamati	0.55	0.32	0	0.64	0.5	0	0	**0.33**
Habiganj	0.72	0.87	1	0.51	0	0	0	**0.70**
Maulvibazar	0.72	0.87	0	0.51	1	0	0	**0.70**
Sunamganj	1.00	0.22	1	1.00	0	0	0	**0.74**
Sylhet	1.00	0.22	0	1.00	1	0	0	**0.74**

[1]*Here, MaxT = Daily Maximum Temperature; MinT = Daily Minimum Temperature; FPT = Future Projected Temperature; DR = Daily total Rainfall; FPP = Future Projected Precipitation; SLR = Sea Level Rise; SS = Storm Surge.*

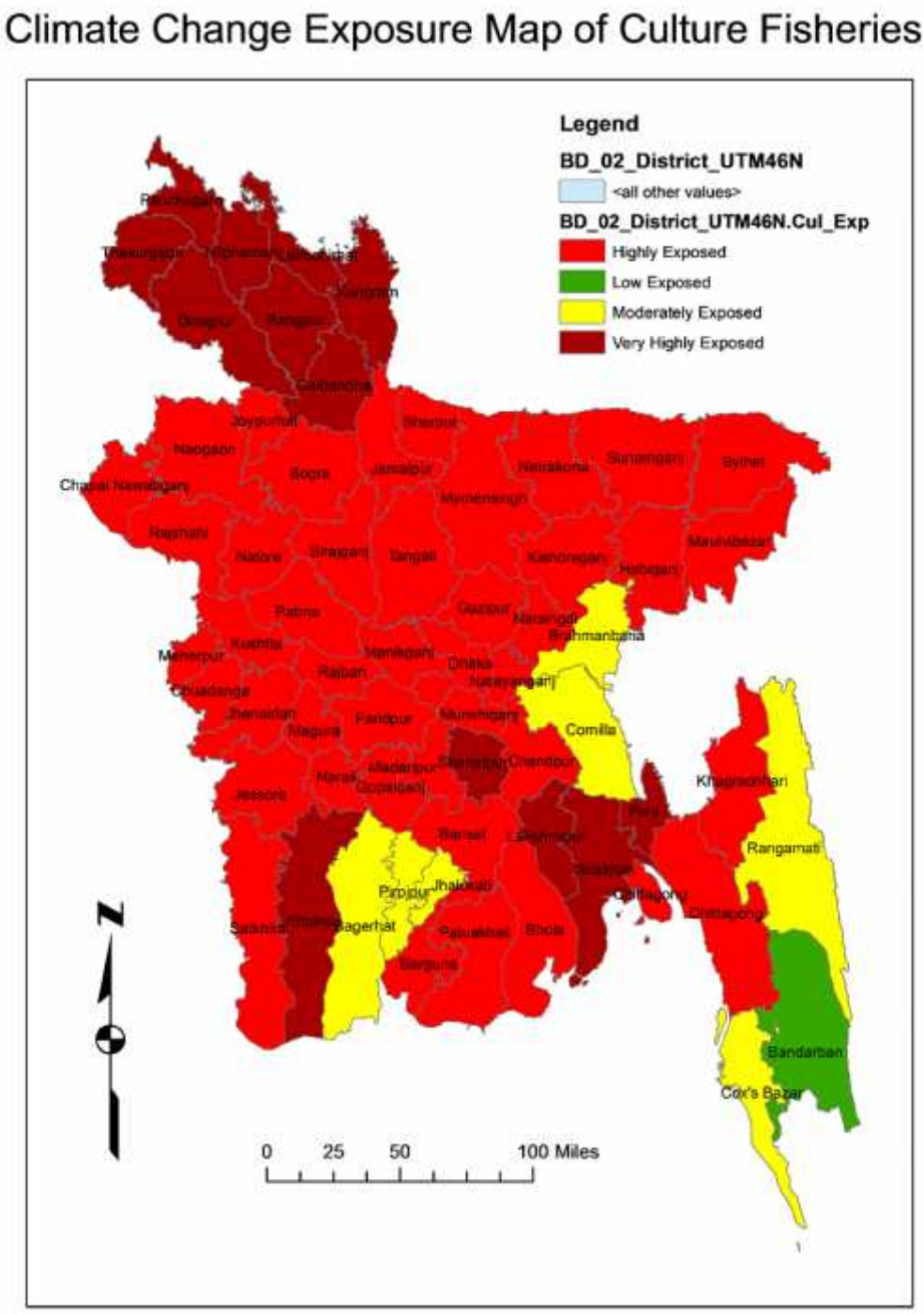


Figure 4: Exposure of culture fisheries of Bangladesh to climate change.

Table 14: Districts with various category of exposure level on culture fisheries sector in Bangladesh.

Very High	**High**		**Moderate**	**Low**
Panchagarh	Sunamganj	Gopalganj	Bagerhat	Bandarban
Thakurgaon	Sylhet	Joypurhat	Pirojpur	
Nilphamari	Maulvibazar	Naogaon	Brahmanbaria	
Lalmonirhat	Habiganj	Bogra	Comilla	
Dinajpur	Sherpur	C. Nawabganj	Rangpur	
Rangpur	Jamalpur	Rajshahi	Cox's Bazar	
Kurigram	Netrakona	Natore	Jhalokati	
Gaibandha	Mymensingh	Pabna		
Khulna	Kishoreganj	Kushtia		
Shariatpur	Narsingdi	Meherpur		
Lakshmipur	Gazipur	Chuadanga		
Noakhali	Tangail	Jhenaidah		
Feni	Sirajganj	Magura		
	Manikganj	Jessore		
	Dhaka	Narail		
	Narayanganj	Satkhira		
	Munshiganj	Chandpur		
	Rajbari	Barisal		
	Faridpur	Barguna		
	Madaripur	Patuakhali		
	Chittagong	Bhola		
	Khagrachhari			

3.1.2 Sensitivity

Highly sensitive district for culture fisheries is Satkhira and Cox's Bazar on the other hand Mymensingh is in low sensitive category (see Table 15, Table 16 and Figure 5). Table 15 is representing the normalized value of sensitivity along with the production and area (both are normalized value) of culture fisheries which has been used as the indicators of sensitivity in this study. Figure 5 is showing the sensitivity map of culture fisheriesbased on the indicators of sensitivity. The map has been divided into four category (very highly sensitive, highly sensitive, moderately sensitive and low sensitive) based on their normalized value of sensitivity. For culture fisheries about 76% of the districts (49 districts) fall into moderately sensitive area which include North and East Bengal and Twelve (12) of them are in highly sensitive category. Table 16 is describing the districts with their category.

Table 15: By district value of sensitivity to climate change on culture fisheries sector in Bangladesh.

Districts	***Culture Production***	***Culture area***	***Sensitivity***
Dhaka	0.98	0.05	***0.47***
Faridpur	0.97	0.11	***0.50***
Gazipur	0.93	0.08	***0.46***
Gopalganj	0.94	0.09	***0.47***
Jamalpur	0.96	0.08	***0.48***
Kishoreganj	0.95	0.06	***0.46***
Madaripur	0.99	0.09	***0.51***
Manikganj	0.99	0.04	***0.47***
Munshiganj	0.98	0.07	***0.49***
Mymensingh	0.00	0.38	***0.00***
Narayanganj	0.98	0.06	***0.48***
Narsingdi	0.96	0.21	***0.57***
Netrakona	0.94	0.08	***0.47***
Rajbari	0.98	0.04	***0.46***
Shariatpur	0.98	0.05	***0.47***
Sherpur	0.95	0.05	***0.45***
Tangail	0.89	0.12	***0.45***
Bagerhat	0.85	0.35	***0.60***
Chuadanga	0.98	0.01	***0.45***

Jessore	0.62	0.38	***0.45***
Jhenaidah	0.95	0.05	***0.45***
Khulna	0.92	0.28	***0.60***
Kushtia	0.96	0.04	***0.45***
Magura	0.98	0.02	***0.45***
Meherpur	0.99	0.00	***0.44***
Narail	0.96	0.02	***0.44***
Satkhira	0.76	1.00	***1.00***
Barguna	0.96	0.06	***0.46***
Barisal	0.91	0.39	***0.67***
Bhola	0.93	0.16	***0.51***
Jhalokati	0.99	0.03	***0.46***
Patuakhali	0.95	0.18	***0.54***
Pirojpur	0.97	0.24	***0.61***
Dinajpur	0.93	0.27	***0.59***
Gaibandha	0.96	0.03	***0.44***
Kurigram	0.96	0.05	***0.45***
Lalmonirhat	0.98	0.05	***0.47***
Nilphamari	0.98	0.02	***0.45***
Panchagarh	0.98	0.04	***0.47***
Rangpur	0.96	0.06	***0.46***
Thakurgaon	0.96	0.07	***0.47***
Bogra	0.85	0.18	***0.47***
Chapai Nawabganj	0.97	0.08	***0.49***
Joypurhat	0.96	0.04	***0.45***
Naogaon	0.85	0.16	***0.46***
Natore	0.93	0.08	***0.46***
Pabna	0.88	0.18	***0.49***
Rajshahi	0.83	0.20	***0.47***
Sirajganj	0.90	0.09	***0.44***
Bandarban	1.00	0.00	***0.45***
Brahmanbaria	0.91	0.11	***0.47***
Chandpur	0.84	0.19	***0.47***
Chittagong	0.84	0.31	***0.56***
Comilla	0.58	0.62	***0.59***
Cox's Bazar	0.88	0.63	***0.82***
Feni	0.93	0.07	***0.45***
Khagrachhari	0.99	0.02	***0.46***
Lakshmipur	0.89	0.13	***0.46***
Noakhali	0.80	0.21	***0.45***
	0.98	0.00	***0.44***

Rangamati	0.92	0.03	***0.41***
Habiganj	0.92	0.04	***0.42***
Maulvibazar	0.87	0.16	***0.47***
Sunamganj	0.89	0.05	***0.41***
Sylhet			

Table 16: Districts with various category of sensitivity level on culture fisheries sector in Bangladesh.

Very High	**High**	**Moderate**			**Low**
Satkhira	Barisal	Dhaka	Bogra	Lakshmipur	Mymensingh
Cox's Bazar	Faridpur	Jessore	Joypurhat	Rangamati	
	Bhola	Gopalganj	Naogaon	Habiganj	
	Madaripur	Jamalpur	Natore	Maulvibazar	
	Patuakhali	Kishoreganj	Kushtia	Khagrachhari	
	Chittagong		Pabna	Lalmonirhat	
	Narsingdi	Manikganj	Sirajganj	Nilphamari	
	Comilla	Munshiganj	Chuadanga	Panchagarh	
	Dinajpur	Tangail	Jhenaidah	Rangpur	
	Bagerhat	Narayanganj	C. Nawabganj	Brahmanbaria	
	Khulna	Thakurgaon	Magura	Jhalokati	
	Pirojpur	Netrakona	Meherpur	Gaibandha	
		Rajbari	Narail	Kurigram	
		Shariatpur	Barguna	Chandpur	
		Sherpur		Noakhali	
		Bandarban	Sunamganj	Rajshahi	
		Feni	Sylhet		

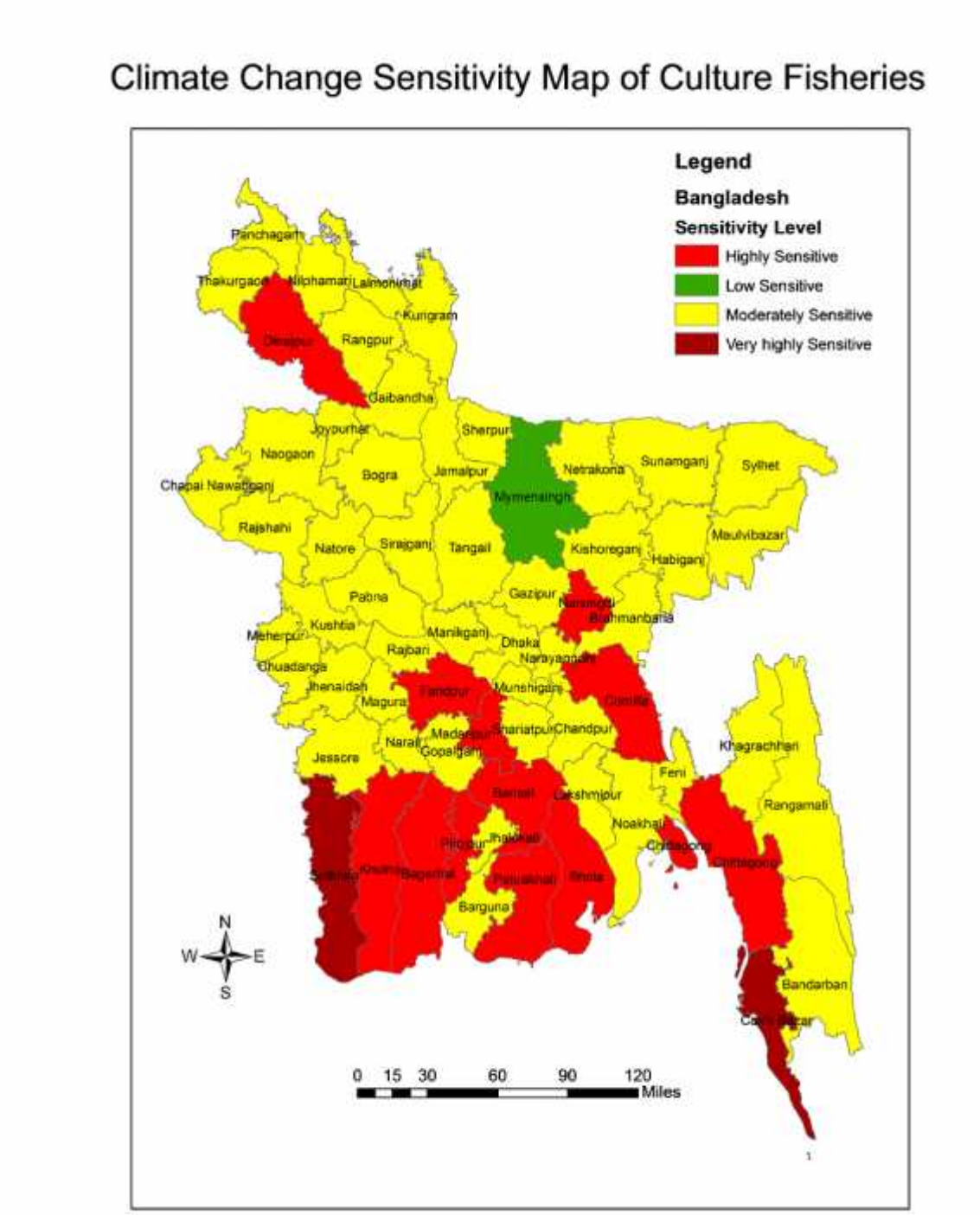


Figure5: Sensitivity of culture fisheries of Bangladesh to climate change.

3.1.3 Adaptive Capacity

The values of adaptive capacity (normalized) is shown in Table 17 with all its indicators and their values (normalized) which has been used to calculate adaptive capacity of culture fisheries (also include capture and overall fisheries sector) to climate change. The study found that the adaptive capacity of Dhaka, Comilla and Chittagong districts are very high. Another six (6) districts, Jessore, Khulna, Barisal, Mymensingh and Narayanganj have high adaptive capacity (see Table 17, Table 18 and Figure 6). Twenty-five districts have moderate adaptive capacity and about 46% districts (30 districts) have low adaptive capacity (detailed list of districts are given in Table 18). This categorization has been done based on the quartile value mentioned in table 12. Figure 6 is showing the adaptive capacity map of culture (including capture and overall fisheries) fisheries of Bangladesh to climate change.

Table 17: By district value of adaptive capacity to climate change on culture fisheries sector (adaptive capacity of capture and overall fisheries sector are also same) in Bangladesh[2].

Districts	***Pov***	***GDP***	***LR***	***EC***	***HS***	***ME***	***PR***	***PS***	***SS***	***TW***	***AC***
Dhaka	0.2	1	1	1	1	0.84	0.38	0.37	0.17	0.58	***1.00***
Faridpur	0.54	0.14	0.39	0.37	0.09	0.24	0.28	0.38	0.06	0.28	***0.24***
Gazipur	0.26	0.5	0.78	0.83	0.24	0.65	0.53	0.35	0.08	0.31	***0.59***
Gopalganj	0.65	0.18	0.65	0.38	0.07	0.23	0.3	0.28	0.05	0.17	***0.27***
Jamalpur	0.79	0.2	0.1	0.25	0.02	0.02	0.33	0.7	0.09	0.45	***0.31***
Kishoreganj	0.44	0.11	0.17	0.38	0.04	0.28	0.52	0.38	0.06	0.51	***0.27***
Madaripur	0.52	0.22	0.37	0.51	0.09	0.25	0.11	0.07	0.04	0.18	***0.13***
Manikganj	0.25	0.26	0.4	0.42		0.32	0.21	0.15	0.04	0.24	***0.13***
Munshiganj	0.42	0.12	0.59	0.91	0.05	0.33	0.42	0.14	0.03	0.16	***0.32***
Mymensingh	0.78	0.19	0.24	0.28	0.16	0.25	0.71	0.45	0.15	0.96	***0.51***
Narayanganj	0.37	0.55	0.62	0.98	0.06	0.44	0.27	0.13	0.05	0.47	***0.53***
Narsingdi	0.33	0.3	0.41	0.69	0.44	0.44	0.49	0.17	0.06	0.28	***0.33***
Netrakona	0.53	0.17	0.13	0.13	0.14	0.2	0.32	0.29	0.06	0.42	***0.13***
Rajbari	0.64	0.19	0.49	0.33	0.01	0.13	0.1	0.16	0.04	0.14	***0.12***
Shariatpur	0.82	0.14	0.35	0.3	0.05	0.19	0.09	0.19	0.03	0.17	***0.13***
Sherpur	0.75	0.23	0.08	0.27	0.04	0.06	0.24	0.15	0.04	0.27	***0.12***
Tangail	0.43	0.15	0.33	0.47	0.15	0.39	0.52	0.39	0.12	0.66	***0.40***
Bagerhat	0.65	0.57	0.67	0.27	0.04	0.14	0.4	0.34	0.08	0.14	***0.36***
Chuadanga	0.4	0.22	0.31	0.53	0.09	0.23	0	0.19	0.03	0.18	***0.18***

Jessore	0.59	0.35	0.61	0.53	0.47	0.13	0.44	0.59	0.13	0.49	***0.55***
Jhenaidah	0.35	0.23	0.31	0.5	0.35	0.54	0.57	0.25	0.07	0.31	***0.36***
Khulna	0.59	0.8	0.71	0.57	0.31	0.2	0.48	0.5	0.1	0.38	***0.65***
Kushtia	0	0.25	0.32	0.57	0.39	0.87	0.24	0.4	0.07	0.36	***0.34***
Magura	0.7	0.25	0.44	0.27	0.15	0.28	0.29	0.1	0.04	0.12	***0.18***
Meherpur	0.19	0.28	0.32	0.53	0.1	0.53	0.09	0.13	0.03	0.12	***0.19***
Narail	0.27	0.32	0.74	0.33	0.43	0.31	0.11	0.14	0.03	0.1	***0.16***
Satkhira	0.71	0.3	0.48	0.28	0.12	0.17	0.2	0.33	0.08	0.31	***0.32***
Barguna	0.26	0.37	0.64	0.11	0.3	0.53	0.14	0.33	0.04	0.12	***0.20***
Barisal	0.85	0.32	0.74	0.43	0.02	0.16	0.3	0.77	0.11	0.42	***0.58***
Bhola	0.49	0.3	0.23	0.08	0.14	0.3	0.24	0.44	0.07	0.27	***0.18***
Jhalokati	0.61	0.14	0.89	0.38	0.02	0.31	0.21	0.21	0.05	0.11	***0.28***
Patuakhali	0.37	0.33	0.54	0.15	0.13	0.36	0.32	0.4	0.07	0.25	***0.26***
Pirojpur	0.67	0.21	0.84	0.3	0.04	0.18	0.21	0.31	0.07	0.15	***0.28***
Dinajpur	0.57	0.24	0.49	0.25	0.07	0.3	0.55	0.17	0.17	0.57	***0.35***
Gaibandha	0.74	0.11	0.22	0.12	0.1	0.1	0.33	0.57	0.1	0.45	***0.26***
Kurigram	1	0.25	0.21	0.01	0.02	0	0.33	0.24	0.09	0.37	***0.17***
Lalmonirhat	0.51	0.19	0.31	0	0	0.04	0.16	0.22	0.05	0.25	***0.02***
Nilphamari	0.52	0.08	0.26	0.19	0.02	0.17	0.16	0.22	0.07	0.32	***0.08***
Panchagarh	0.38	0.14	0.47	0.09	0.04	0.3	0.14	0	0.07	0.15	***0.04***
Rangpur	0.71	0.18	0.38	0.23	0.22	0.34	0.47	0.2	0.13	0.6	***0.33***
Thakurgaon	0.39	0.28	0.39	0.19	0.06	0.39	0.15	0.12	0.1	0.24	***0.12***
Bogra	0.22	0.23	0.4	0.42	0.04	0.28	0.9	0.08	0.12	0.68	***0.35***
C. Nawabganj	0.36	0.09	0.22	0.37	0.11	0.3	0.24	0.16	0.06	0.27	***0.14***
Joypurhat	0.38	0.36	0.63	0.41	0.27	0.32	0.19	0.15	0.04	0.18	***0.22***
Naogaon	0.22	0.28	0.37	0.25	0.11	0.36	0.69	0.34	0.11	0.51	***0.33***
Natore	0.52	0.32	0.41	0.37	0.1	0.12	0.38	0.11	0.08	0.34	***0.21***
Pabna	0.46	0.34	0.33	0.52	0.1	0.23	0.66	0.26	0.08	0.46	***0.38***
Rajshahi	0.46	0.37	0.51	0.55	0.14	0.25	0.66	0.23	0.14	0.46	***0.45***
Sirajganj	0.58	0.11	0.51	0.35	0.27	0.16		0.4	0.1	0.53	***0.19***
Bandarban	0.61	0.11	0.02	0.11	0.03	0.36	0.35	0.08	0.01	0	***0.00***
Brahmanbaria	0.44	0.09	0.29	0.67	0.06	0.37	0.35	0.26	0.06	0.38	***0.29***
Chandpur	0.79	0.18	0.61	0.46	0.16	0.15	0.38	0.33	0.07	0.4	***0.39***
Chittagong	0.13	0.73	0.67	0.77	0.14	0.89	0.61	0.78	0.18	1	***1.00***
Comilla	0.57	0	0.52	0.71	0.54	0.31	1	1	0.15	0.78	***0.81***
Cox's Bazar	0.48	0.25	0.12	0.16	0.2	0.31	0.52	0.23	0.04	0.26	***0.17***
Feni	0.37	0.04	0.69	0.69	0.12	0.82	0.38	0.18	0.05	0.2	***0.42***
Khagrachhari	0.36	0	0.31	0.16	0.35	0.36	0.43	0.3	0.02	0.09	***0.09***
Lakshmipur	0.46	0.15	0.41	0.31	0.03	0.47	0.37	0.17	0.04	0.29	***0.23***
Noakhali	0.1	0.12	0.46	0.4	0.15	1	0.45	0.47	0.08	0.43	***0.43***
Rangamati	0.28	0.29	0.41	0.28	0.15	0.48	0.18	0.19	0.03	0.05	***0.13***
Habiganj	0.36	0.08	0.16	0.36	0.09	0.21	0.33	0.32	0.03	0.26	***0.13***
Maulvibazar	0.37	0.1	0.45	0.4	0.1	0.29	0.33	0.27	0.05	0.25	***0.23***

Sunamganj	0.37	0.03	0	0.18	0.25	0.15	0.24	0.35	0.05	0.36	***0.06***
Sylhet	0.34	0.18	0.46	0.56	0.13 0.47	0.57	0.71	0.34	0.08	0.32	***0.49***

[2]Here, Pov = Poverty; GDP = Gross District Product; LR = Literacy Rate; EC = Electricity Coverage; HS = Household Structure; ME = monthly Expenditure; PR = Paved Road; PS = Primary School; SS = Secondary School; TW = Tube Well; AC= Adaptive Capacity.

Table 18: Districts with various category of adaptive capacity level on culture fisheries sector (also include capture and overall fisheries sector) in Bangladesh.

Low Adaptive Capacity		**Moderate Adaptive Capacity**		**High Adaptive Capacity**	**Very High Adaptive Capacity**
Panchagarh	Maulvibazar	Dinajpur	Jhalokati	Jessore	Dhaka
Thakurgaon	Manikganj	Rangpur	Patuakhali	Khulna	Comilla
Nilphamari	Rajbari	Gaibandha	Munshiganj	Barisal	Chittagong
Lalmonirhat	Faridpur	Naogaon	Chandpur	Gazipur	
Kurigram	Magura	Bogra	Noakhali	Mymensingh	
Joypurhat	Narail	Jamalpur	Feni	Narayanganj	
C. Nawabganj	Madaripur	Tangail	Brahmanbaria		
Natore	Shariatpur	Rajshahi	Narsingdi		
Sirajganj	Barguna	Pabna	Kishoreganj		
Meherpur	Bhola	Kushtia	Sylhet		
Chuadanga	Lakshmipur	Jhenaidah			
Sherpur	Khagrachhari	Satkhira			
Netrakona	Rangamati	Bagerhat			
Sunamganj	Cox's Bazar	Gopalganj			
Habiganj	Bandarban	Pirojpur			

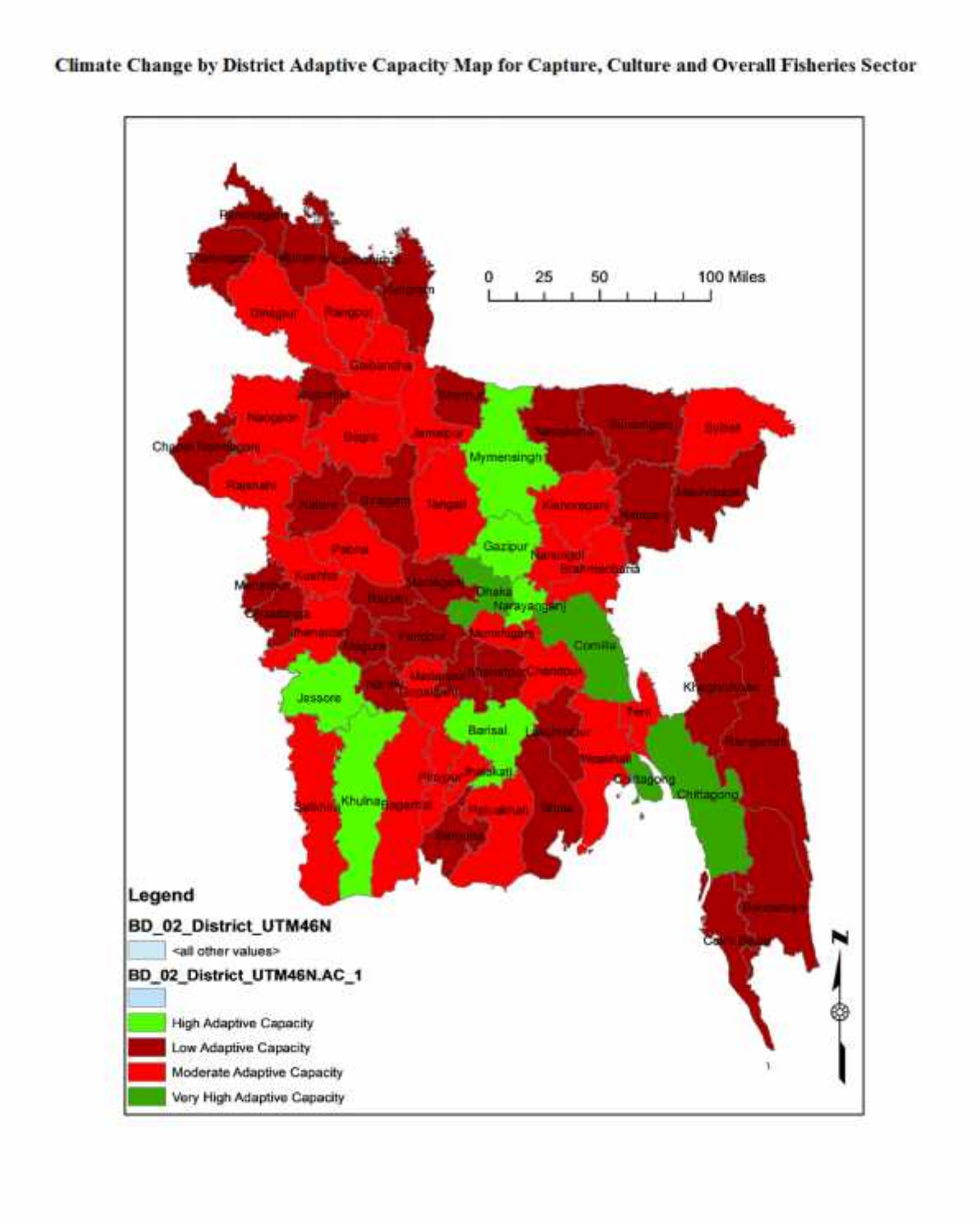


Figure6: Adaptive capacity of culture, capture and overall fisheries of Bangladesh to climate change.

3.1.4 Vulnerability

As mentioned above (section 3.1) that the vulnerability of culture fisheries is the combined effect of exposure, sensitivity and adaptive capacity, so the vulnerability of a district depends on its value of exposure, sensitivity and specially the adaptive capacity. Because the more adaptive capacity is, the less the vulnerability will be. The overall vulnerability value (normalized) of Culture fisheries for various districts is shown in Table 19.Figure 7 is the map based on the quartile value of vulnerability of culture fisheries. The study has found that, twelve (12) districts namely Gaibandha, Lakshmipur, Rangpur, Shariatpur, Sunamganj, Dinajpur, Kurigram, Satkhira, Thakurgaon, Nilphamari, Lalmonirhat and Panchagarh have very high vulnerability. Most of the districts are in the north side of Bangladesh. Among the coastal districts which are very highly exposed to climatic hazards Satkhira and Lakshmipur are very highly vulnerable.

Table 19: Values of vulnerability of culture fisheries along with the values of exposure, sensitivity and adaptive capacity of 64 districts of Bangladesh.

Districts	***Exposure***	***Sensitivity***	***Adaptive Capacity***	***Vulnerability***
Dhaka	0.59	0.47	**1.00**	***0.00***
Faridpur	0.55	0.50	0.24	***0.54***
Gazipur	0.59	0.46	0.59	***0.29***
Gopalganj	0.50	0.47	0.27	***0.47***
Jamalpur	0.55	0.48	0.31	***0.48***
Kishoreganj	0.60	0.46	0.27	***0.53***
Madaripur	0.50	0.51	0.13	***0.60***
Manikganj	0.59	0.47	0.13	***0.63***
Munshiganj	0.59	0.49	0.32	***0.51***
Mymensingh	0.60	**0.00**	0.51	***0.02***
Narayanganj	0.59	0.48	0.53	***0.35***
Narsingdi	0.59	0.57	0.33	***0.57***
Netrakona	0.60	0.47	0.13	***0.64***
Rajbari	0.55	0.46	0.12	***0.60***
Shariatpur	0.78	0.47	0.13	***0.77***
Sherpur	0.60	0.45	0.12	***0.64***
Tangail	0.58	0.45	0.40	***0.42***

Bagerhat	0.41	0.60	0.36	***0.43***
Chuadanga	0.62	0.45	0.18	***0.60***
Jessore	0.61	0.45	0.55	***0.33***
Jhenaidah	0.61	0.45	0.36	***0.47***
Khulna	0.91	0.60	0.65	***0.58***
Kushtia	0.64	0.45	0.34	***0.50***
Magura	0.61	0.45	0.18	***0.60***
Meherpur	0.62	0.44	0.19	***0.59***
Narail	0.61	0.44	0.16	***0.61***
Satkhira	0.60	**1.00**	0.32	***0.89***
Barguna	0.51	0.46	0.20	***0.52***
Barisal	0.54	0.67	0.58	***0.41***
Bhola	0.71	0.51	0.18	***0.72***
Jhalokati	0.48	0.46	0.28	***0.44***
Patuakhali	0.63	0.54	0.26	***0.62***
Pirojpur	0.38	0.61	0.28	***0.47***
Dinajpur	0.98	0.59	0.35	***0.85***
Gaibandha	0.93	0.44	0.26	***0.77***
Kurigram	0.98	0.45	0.17	***0.88***
Lalmonirhat	0.98	0.47	0.02	***1.00***
Nilphamari	**1.00**	0.45	0.08	***0.96***
Panchagarh	**1.00**	0.47	0.04	***1.00***
Rangpur	0.98	0.46	0.33	***0.77***
Thakurgaon	0.98	0.47	0.12	***0.93***
Bogra	0.55	0.47	0.35	***0.45***
C. Nawabganj	0.64	0.49	0.14	***0.68***
Joypurhat	0.55	0.45	0.22	***0.52***
Naogaon	0.64	0.46	0.33	***0.52***
Natore	0.64	0.46	0.21	***0.60***
Pabna	0.64	0.49	0.38	***0.50***
Rajshahi	0.64	0.47	0.45	***0.44***
Sirajganj	0.59	0.44	0.19	***0.58***
Bandarban	**0.00**	0.45	**0.00**	***0.28***
Brahmanbaria	0.49	0.47	0.29	***0.44***
Chandpur	0.72	0.47	0.39	***0.54***
Chittagong	0.59	0.56	**1.00**	***0.07***
Comilla	0.49	0.59	0.81	***0.15***
Cox's Bazar	0.43	0.82	0.17	***0.74***
Feni	0.96	0.45	0.42	***0.67***
Khagrachhari	0.66	0.46	0.09	***0.70***
Lakshmipur	0.88	0.46	0.23	***0.77***

Noakhali	0.97	0.45	0.43	***0.68***
Rangamati	0.33	0.44	0.13	***0.42***
Habiganj	0.70	0.41	0.13	***0.67***
Maulvibazar	0.70	0.42	0.23	***0.60***
Sunamganj	0.74	0.47	0.06	***0.79***
Sylhet	0.74	0.41	0.49	***0.43***

The reasons of very high vulnerability of Satkhira and Lakshmipurdistricts are, Lakshmipur is very highly exposed to climatic hazards with a moderate sensitivity, but the adaptive capacity of Lakshmipur district is very low which made this district very highly vulnerable. Additionally, Satkhira district has high exposure with very high sensitivity. Moreover adaptive capacity of this district is moderate which made this district very highly vulnerable. On the other hand Dhaka, Chittagong, Mymensingh and Comilla districts have the lowest value of vulnerability in culture fisheries because of very high adaptive capacity. Moreover Mymensingh district have the lowest sensitivity in culture fisheries sector because fish production from culture fisheries in Mymensingh district is very high (301914 MT) (FRSS 2015). Thirty-one (31) districts of Bangladesh (see Table 19 and Figure 7 are highly vulnerable to climate variability and change. Seventeen (17) districts has fallen in moderately vulnerable category. Name of the districts along with their category are given in Table 20.

The results of culture fisheries vulnerability have showed that there are strong spatial pattern in terms of vulnerability of culture fisheries in Bangladesh. In particular, result suggests that the vulnerability of north-western districts of Bangladesh is very high (Figure 7). Shahid and Behrawan (2008) found northern and northwestern districts of Bangladesh highest risk to drought. So the possible reason of very high vulnerability in culture fisheries could be lack of water supply in the dry season. This study also find the northwestern districts of Bangladesh very highly exposed to climatic variability and change (Figure 4) though the sensitivity of these districts are moderate (Figure 5). But the adaptive capacity of these districts are low to moderate (Figure 6). Among the very high vulnerable districts Lalmonirhat has the highest vulnerability which has very highly exposed, moderate sensitivity and low capacity to adapt. On the other hand among the low vulnerable districts,

Dhaka has the lowest vulnerability which is highly exposed to climatic variability and change, moderate sensitivity but very higher capacity to adapt.

Climate Change Vulnerability Map of Culture Fisheries

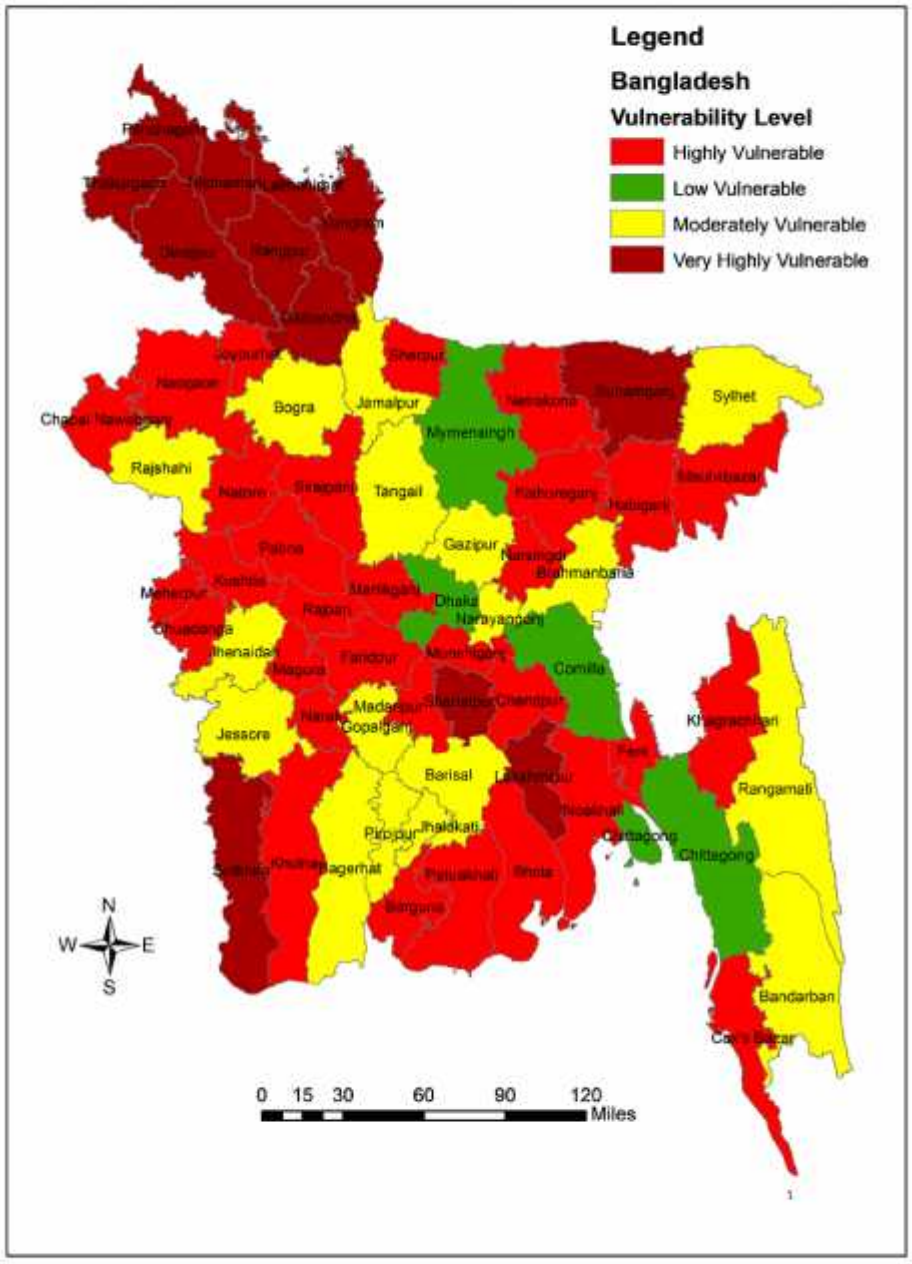


Figure7: Vulnerability of culture fisheries of Bangladesh to climate change.

Table 20: Districts with various category of vulnerability to climate change on culture fisheries sector in Bangladesh.

Very High	**High**		**Moderate**	**Low**
Gaibandha	Kushtia	Natore	Bandarban	Dhaka
Lakshmipur	Pabna	Rajbari	Gazipur	Chittagong
Rangpur	Munshiganj	Narail	Jessore	Mymensingh
Shariatpur	Barguna	Patuakhali	Narayanganj	Comilla
Sunamganj	Joypurhat	Manikganj	Barisal	
Dinajpur	Naogaon	Netrakona	Rangamati	
Kurigram	Kishoreganj	Sherpur	Tangail	
Satkhira	Chandpur	Feni	Bagerhat	
Thakurgaon	Faridpur	Habiganj	Sylhet	
Nilphamari	Narsingdi	C. Nawabganj	Brahmanbaria	
Lalmonirhat	Khulna	Noakhali	Jhalokati	
Panchagarh	Sirajganj	Khagrachhari	Rajshahi	
	Meherpur	Bhola	Bogra	
	Chuadanga	Cox's Bazar	Gopalganj	
	Madaripur		Jhenaidah	
	Magura		Pirojpur	
	Maulvibazar		Jamalpur	

3.2 Vulnerability of Capture Fisheries

As mentioned above (section 3.1) that exposure, sensitivity and adaptive capacity combined to create vulnerability. For weighting vulnerability of capture fisheries exposure sensitivity and adaptive capacity are given below.

3.2.1 Exposure

This study has showed that ten (10) districts are very highly exposed to climate change in capture fisheries sector. These districts are- Kurigram, Gaibandha, Khulna, Shariatpur, Chandpur, Lakshmipur, Feni, Noakhali, Patuakhali and Bhola; most of them are coastal. Table 21 is representing the normalized value of exposure for each districts along with their values of indicators (normalized). The categorization has been done based on the quartile value mentioned in Table 12.However, Figure 8 is illustrating the exposure map of capture fisheries sector to climate change. About 50% of them (30 districts) are moderately exposed and only Rangamati and Bandarban are low exposed district. Table 22 is showing the name of the districts according to their exposure level for capture fisheries.

Table 21: By district value of exposure to climate change on capture fisheries sector in Bangladesh[3].

Districts	***MaxT***	***MinT***	***FPT***	***DR***	***FPP***	***SLR***	***Ero***	***SS***	***Cyc***	***E***
Dhaka	0.53	0.81	1	0.45	0	0	0	0	0	***0.36***
Faridpur	0.56	0.72	1	0.37	0	0	1	0	0	***0.54***
Gazipur	0.53	0.81	1	0.45	0	0	0	0	0	***0.36***
Gopalganj	0.47	0.66	1	0.4	0	0	0	0	0	***0.31***
Jamalpur	0.75	0.61	1	0.31	0	0	1	0	0	***0.54***
Kishoreganj	0.69	0.68	1	0.44	0	0	0	0	0	***0.37***
Madaripur	0.47	0.66	1	0.4	0	0	0	0	0	***0.31***
Manikganj	0.53	0.81	1	0.45	0	0	0	0	0	***0.36***
Munshiganj	0.53	0.81	1	0.45	0	0	1	0	0	***0.56***
Mymensingh	0.69	0.68	1	0.44	0	0	0	0	0	***0.37***
Narayanganj	0.53	0.81	1	0.45	0	0	0	0	0	***0.36***
Narsingdi	0.53	0.81	1	0.45	0	0	0	0	0	***0.36***
Netrakona	0.69	0.68	1	0.44	0	0	0	0	0	***0.37***
Rajbari	0.56	0.72	1	0.37	0	0	1	0	0	***0.54***
Shariatpur	0.42	0.51	1	0.41	0	0	1	1	1	***0.88***
Sherpur	0.69	0.68	1	0.44	0	0	0	0	0	***0.37***
Tangail	0.71	0.67	1	0.37	0	0	1	0	0	***0.56***
Bagerhat	0.51	0.4	0	0.32	0	0	0	1	1	***0.45***

Chuadanga	0.77	0.89	1	0.19	0	0	0	0	0	***0.37***
Jessore	0.65	0.93	1	0.27	0	0	0	0	0	***0.37***
Jhenaidah	0.71	0.91	1	0.23	0	0	0	0	0	***0.37***
Khulna	0.57	0.85	0	0.33	0	1	0	1	1	***0.76***
Kushtia	0.77	0.91	1	0.24	0	0	1	0	0	***0.59***
Magura	0.65	0.93	1	0.27	0	0	0	0	0	***0.37***
Meherpur	0.77	0.89	1	0.19	0	0	0	0	0	***0.37***
Narail	0.65	0.93	1	0.27	0	0	0	0	0	***0.37***
Satkhira	0.51	1	0	0.3	0	0	0	1	1	***0.57***
Barguna	0.11	0.72	0	0.72	0	0	0	1	1	***0.51***
Barisal	0.38	0.76	0.5	0	0	0	1	1	1	***0.74***
Bhola	0.28	0.65	0	0.46	0	0.77	1	1	1	***0.84***
Jhalokati	0.31	0.52	0	0.62	0	0	0	1	1	***0.50***
Patuakhali	0.31	0.52	0	0.62	0	0.45	1	1	1	***0.79***
Pirojpur	0.38	0.76	0	0	0	0	0	1	1	***0.43***
Dinajpur	0.88	0.58	1	0.49	1	0	0	0	0	***0.6***
Gaibandha	0.78	0.59	1	0.44	1	0	1	0	0	***0.77***
Kurigram	0.82	0.58	1	0.56	1	0	1	0	0	***0.80***
Lalmonirhat	0.82	0.58	1	0.56	1	0	0	0	0	***0.60***
Nilphamari	0.94	0.52	1	0.55	1	0	0	0	0	***0.61***
Panchagarh	0.94	0.52	1	0.55	1	0	0	0	0	***0.61***
Rangpur	0.82	0.58	1	0.56	1	0	0	0	0	***0.60***
Thakurgaon	0.88	0.58	1	0.49	1	0	0	0	0	***0.60***
Bogra	0.75	0.61	1	0.31	0	0	1	0	0	***0.54***
Nawabganj	0.83	0.89	1	0.21	0	0	1	0	0	***0.59***
Joypurhat	0.75	0.61	1	0.31	0	0	0	0	0	***0.34***
Naogaon	0.83	0.89	1	0.21	0	0	0	0	0	***0.39***
Natore	0.77	0.91	1	0.24	0	0	0	0	0	***0.39***
Pabna	0.77	0.91	1	0.24	0	0	1	0	0	***0.59***
Rajshahi	0.83	0.89	1	0.21	0	0	1	0	0	***0.59***
Sirajganj	0.76	0.76	1	0.28	0	0	1	0	0	***0.57***
Bandarban	0.08	0	0	0.94	0	0	0	0	0	***0.00***
Brahmanbaria	0.45	0.6	1	0.44	0	0	0	0	0	***0.30***
Chandpur	0.37	0.37	1	0.43	0	0	1	1	1	***0.84***
Chittagong	0.16	0.33	0	0.85	0	0.46	0	1	1	***0.57***
Comilla	0.45	0.6	1	0.44	0	0	0	0	0	***0.30***
Cox's Bazar	0	0.05	0	0.94	0	0.31	0	1	1	***0.46***
Feni	0.54	0.61	1	0.74	0	0	0	1	1	***0.79***
Khagrachhari	0.35	0.74	0	0.9	1	0	0	0	0	***0.40***
Lakshmipur	0.42	0.51	0.5	0.81	0	0.41	1	1	1	***0.94***
Noakhali	0.42	0.51	0.5	0.81	0	0.7	1	1	1	***1.00***
Rangamati	0.55	0.32	0	0.64	0.5	0	0	0	0	***0.20***
Habiganj	0.72	0.87	1	0.51	0	0	0	0	0	***0.42***

Maulvibazar	0.72	0.87	0	0.51	1	0	0	0	0	***0.42***
Sunamganj	1	0.22	1	1	0	0	0	0	0	***0.45***
Sylhet	1	0.22	0	1	1	0	0	0	0	***0.45***

[3]*Here, MaxT = Daily Maximum Temperature; MinT = Daily Minimum Temperature; FPT = Future Projected Temperature; DR = Daily total Rainfall; FPP = Future Projected Precipitation; SLR = Sea Level Rise; Ero = Erosion; SS = Storm Surge; Cyc = Cyclone E = Exposure.*

Table 22: Districts with various category of exposure level on capture fisheries sector in Bangladesh.

Low	**Moderate**		**High**	**Very High**
Rangamati	Joypurhat	Madaripur	Panchagarh	Kurigram
Bandarban	Naogaon	Gopalganj	Thakurgaon	Gaibandha
	Natore	Brahmanbaria	Nilphamari	Khulna
	Sherpur	Comilla	Lalmonirhat	Shariatpur
	Mymensingh	Khagrachhari	Dinajpur	Chandpur
	Netrakona	Cox's Bazar	Rangpur	Lakshmipur
	Kishoreganj	Meherpur	Bogra	Feni
	Sunamganj	Jhenaidah	Jamalpur	Noakhali
	Sylhet	Magura	Sirajganj	Patuakhali
	Maulvibazar	Jessore	Tangail	Bhola
	Habiganj	Narail	C. Nawabganj	
	Gazipur	Bagerhat	Rajshahi	
	Narsingdi	Pirojpur	Kushtia	
	Manikganj	Chuadanga	Pabna	
	Dhaka		Rajbari	
	Narayanganj		Faridpur	
			Munshiganj	
			Satkhira	
			Barisal	
			Jhalokati	

			Barguna	
			Chittagong	

Climate Change Exposure Map of Capture and Overall Fisheries of Bangladesh

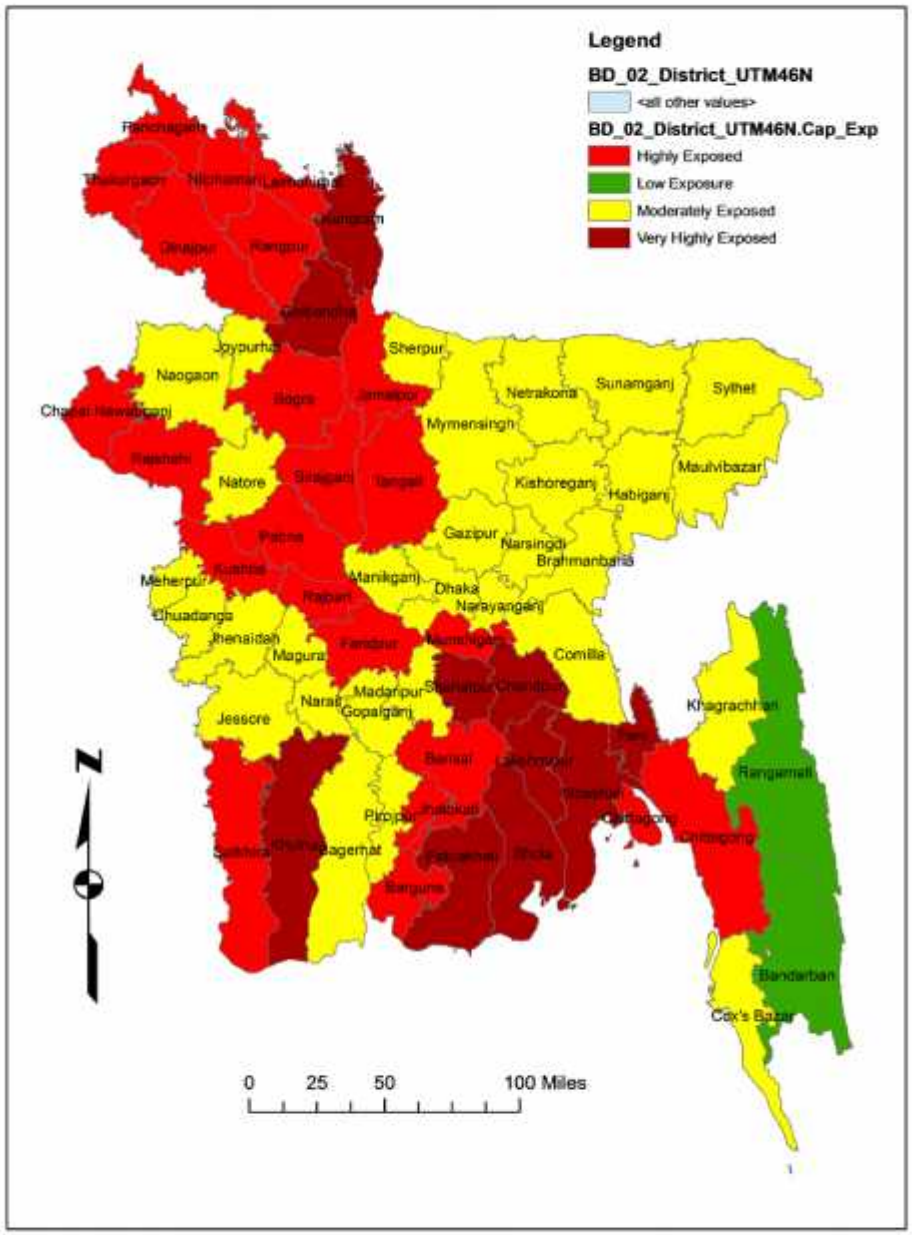


Figure8: Exposure of capture fisheries of Bangladesh to climate.

3.2.2. Sensitivity

Table 23 is showing the normalized value of sensitivity of capture fisheries to climate change with the value of capture production and area value (both are normalized) which has been used as sensitivity indicator in this study. The study has found that, seven (7) districts namely Tangail, Kurigram, Bhola, Bagerhat, Khulna, Patuakhali and Satkhira districts are the very highly sensitive district for capture fisheries. On the other hand, nine (9) districts (Chittagong, Comilla, Dhaka, Gazipur, Sunamganj, Lakshmipur, Feni, Naogaon and Narayanganj) have the lowest sensitivity. Figure 9illustrates the sensitivity map of capture fisheries sector. From the map, it has found that, twenty-seven (27) districts are highly sensitive, twenty-one (21) of them are moderately sensitive. Table 24 is showing the name of the districts following the level of sensitivity.

Table 23: By district value of sensitivity to climate change on capture fisheries sector in Bangladesh.

Districts	***Capture Production***	***Capture Area***	***Sensitivity***
Dhaka	0.47	0.24	***0.19***
Faridpur	0.91	0.54	***0.70***
Gazipur	0.71	0.05	***0.22***
Gopalganj	0.94	0.22	***0.50***
Jamalpur	0.88	0.54	***0.68***
Kishoreganj	0.75	0.46	***0.53***
Madaripur	0.94	0.24	***0.51***
Manikganj	0.92	0.39	***0.60***
Munshiganj	0.83	0.24	***0.44***
Mymensingh	0.58	0.80	***0.65***
Narayanganj	0.63	0.15	***0.24***
Narsingdi	0.86	0.25	***0.46***
Netrakona	0.57	0.41	***0.37***
Rajbari	0.93	0.30	***0.54***
Shariatpur	0.96	0.32	***0.58***
Sherpur	0.85	0.19	***0.42***
Tangail	0.89	0.63	***0.75***
0Bagerhat	0.73	0.95	***0.85***

Chuadanga	0.99	0.29	***0.58***
Jessore	0.69	0.57	***0.56***
Jhenaidah	0.94	0.48	***0.67***
Khulna	0.79	1.00	***0.92***
Kushtia	0.87	0.43	***0.59***
Magura	0.97	0.26	***0.54***
Meherpur	1.00	0.18	***0.51***
Narail	0.98	0.20	***0.51***
Satkhira	0.90	1.00	***1.00***
Barguna	0.72	0.38	***0.45***
Barisal	0.65	0.64	***0.58***
Bhola	0.73	0.91	***0.83***
Jhalokati	0.95	0.19	***0.48***
Patuakhali	0.93	0.85	***0.92***
Pirojpur	0.94	0.29	***0.54***
Dinajpur	0.77	0.26	***0.41***
Gaibandha	0.76	0.58	***0.61***
Kurigram	0.89	0.68	***0.78***
Lalmonirhat	0.94	0.34	***0.58***
Nilphamari	0.94	0.40	***0.62***
Panchagarh	0.95	0.05	***0.39***
Rangpur	0.89	0.48	***0.64***
Thakurgaon	0.83	0.00	***0.28***
Bogra	0.48	0.45	***0.34***
C. Nawabganj	0.92	0.35	***0.57***
Joypurhat	0.84	0.07	***0.32***
Naogaon	0.48	0.29	***0.23***
Natore	0.75	0.36	***0.46***
Pabna	0.66	0.63	***0.58***
Rajshahi	0.48	0.47	***0.36***
Sirajganj	0.6	0.68	***0.58***
Bandarban	1.00	0.00	***0.39***
Brahmanbaria	0.7	0.35	***0.42***
Chandpur	0.42	0.44	***0.29***
Chittagong	0.20	0.24	***0.00***
Comilla	0.00	0.66	***0.16***
Cox's Bazar	0.98	0.03	***0.40***
Feni	0.66	0.13	***0.24***
Khagrachhari	0.99	0.00	***0.38***
Lakshmipur	0.21	0.40	***0.12***
Noakhali	0.14	0.82	***0.36***
Rangamati	0.98	0.18	***0.50***
Habiganj	0.55	0.31	***0.29***

Maulvibazar	0.63	0.26	***0.32***
Sunamganj	0.29	0.27	***0.09***
Sylhet	0.67	0.68	***0.63***

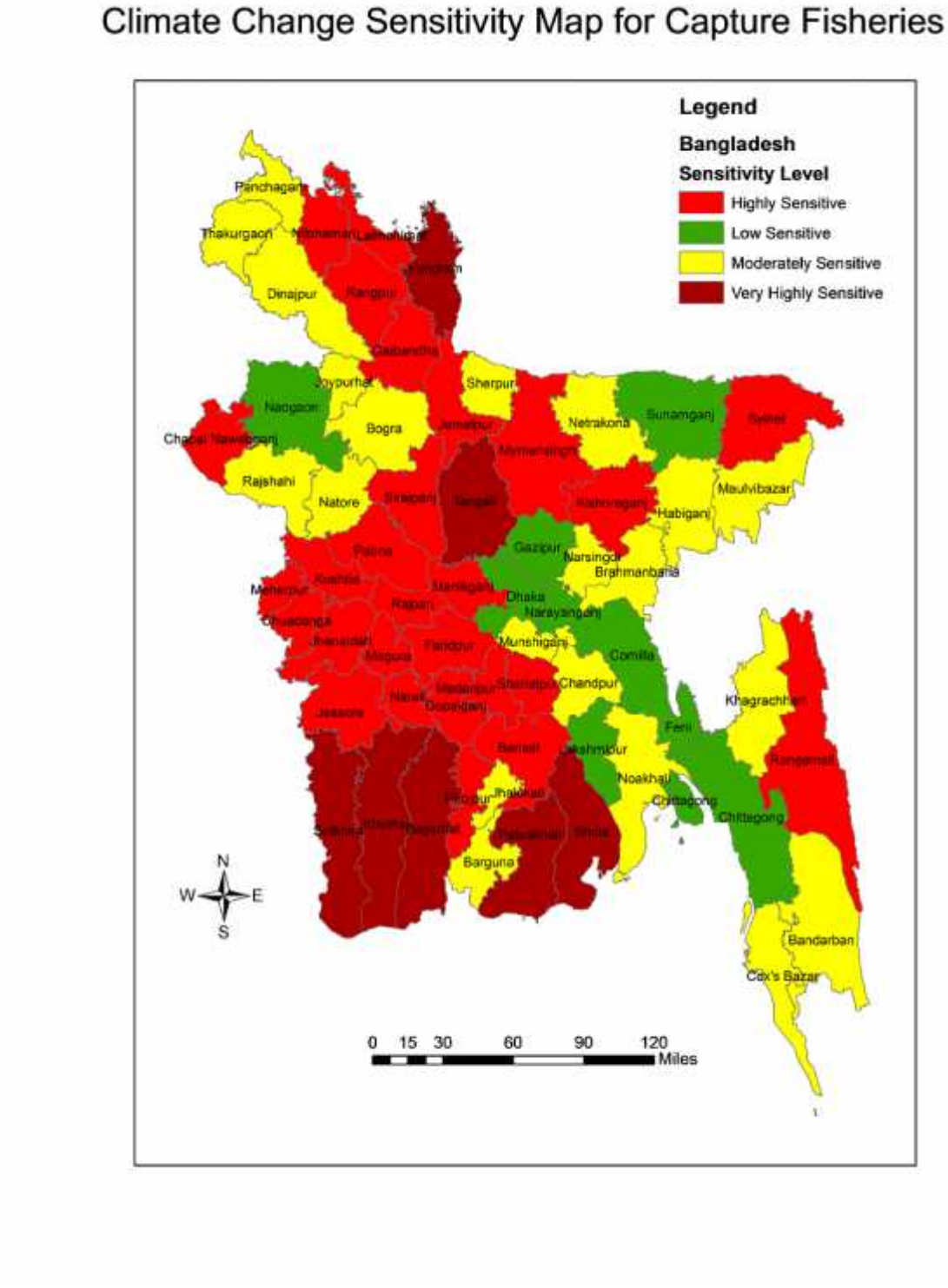


Figure9: Sensitivity of Capture fisheries of Bangladesh to climate change.

Table 24: Districts with various category of sensitivity level on capture fisheries sector in Bangladesh.

Very High	**High**		**Moderate**		**Low**
Tangail	Gopalganj	Pabna	Panchagarh	Thakurgaon	Dhaka
Kurigram	Rangamati	Shariatpur	Cox's Bazar	Chandpur	Sunamganj
Bhola	Madaripur	Sirajganj	Dinajpur	Habiganj	Lakshmipur
Bagerhat	Meherpur	Kushtia	Brahmanbaria	Joypurhat	Comilla
Khulna	C. Nawabganj	Manikganj	Sherpur	Maulvibazar	Narayanganj
Patuakhali	Kishoreganj	Gaibandha	Munshiganj	Bogra	Gazipur
Satkhira	Magura	Nilphamari	Barguna	Noakhali	Naogaon
	Pirojpur	Sylhet	Narsingdi	Rajshahi	Feni
	Rajbari	Rangpur	Natore	Netrakona	Chittagong
	Jessore	Mymensingh	Jhalokati	Khagrachhari	
	Narail	Jhenaidah		Bandarban	
	Barisal	Jamalpur			
	Chuadanga	Faridpur			
	Lalmonirhat				

3.2.3 Adaptive Capacity

The values of adaptive capacity are same like the adaptive capacity of culture and overall fisheries. See section 3.1.3 and table number 17, 18 and Figure 6 for details.

3.2.4 Vulnerability

Table 25 is showing the normalized value of vulnerability along with the values of exposure, sensitivity and adaptive capacity (all values are normalized) by district. Figure 10 is representing the map of vulnerability of capture fisheries sector in Bangladesh. Quartile value (Table 12) has been used to generate the map. The map shows that ten (10) districts (Bhola, Khulna, Gaibandha, Lalmonirhat, Nilphamari, Satkhira, Shariatpur, Kurigram, Patuakhali and Chapai Nawabganj) has very high vulnerability to climate change in capture fisheries sector. Mainly the coastal and north-bengal districts has fallen in very highly vulnerable category.

The study has found that districts with very high vulnerability either very highly exposed or high sensitivity with a very low adaptive capacity which made those districts very highly vulnerable. For example Bhola district has exposed very highly to climatic variable with a very high sensitivity. But the adaptive capacity of this district is very low which made this district very highly vulnerable. Similarly, thirty-nine (39) districts has fallen into the category of highly vulnerable. The study showed that, districts adjacent to the big river (Padma-Meghna-Jamuna)have high vulnerability. Eleven (11)districtshas moderate vulnerability and only four (4) districts (Dhaka, Gazipur, Chittagong and Comilla) haslow vulnerability. Table 26 is describing the name of the districts according to their level of vulnerability.

Table 25: Values of vulnerability of capture fisheries along with the values of exposure, sensitivity and adaptive capacity of 64 districts of Bangladesh.

Districts	***Exposure***	***Sensitivity***	***Adaptive Capacity***	***Vulnerability***
Dhaka	0.50	0.19	**1.00**	***0.00***
Faridpur	0.69	0.70	0.24	***0.74***
Gazipur	0.50	0.22	0.59	***0.23***
Gopalganj	0.47	0.50	0.27	***0.51***
Jamalpur	0.71	0.68	0.31	***0.70***
Kishoreganj	0.51	0.53	0.27	***0.55***

Madaripur	0.47	0.51	0.13	***0.59***
Manikganj	0.50	0.60	0.13	***0.66***
Munshiganj	0.68	0.44	0.32	***0.58***
Mymensingh	0.51	0.65	0.51	***0.49***
Narayanganj	0.50	0.24	0.53	***0.27***
Narsingdi	0.50	0.46	0.33	***0.49***
Netrakona	0.51	0.37	0.13	***0.54***
Rajbari	0.69	0.54	0.12	***0.73***
Shariatpur	0.98	0.58	0.13	***0.92***
Sherpur	0.51	0.42	0.12	***0.58***
Tangail	0.70	0.75	0.40	***0.70***
Bagerhat	0.63	0.85	0.36	***0.72***
Chuadanga	0.61	0.58	0.18	***0.63***
Jessore	0.58	0.56	0.55	***0.43***
Jhenaidah	0.59	0.67	0.36	***0.58***
Khulna	0.90	0.92	0.65	***0.76***
Kushtia	0.78	0.59	0.34	***0.67***
Magura	0.58	0.54	0.18	***0.61***
Meherpur	0.61	0.51	0.19	***0.59***
Narail	0.58	0.51	0.16	***0.61***
Satkhira	0.74	**1.00**	0.32	***0.87***
Barguna	0.54	0.45	0.20	***0.63***
Barisal	**1.00**	0.58	0.58	***0.61***
Bhola	0.93	0.83	0.18	***1.00***
Jhalokati	0.56	0.48	0.28	***0.59***
Patuakhali	0.82	0.92	0.26	***0.98***
Pirojpur	0.73	0.54	0.28	***0.59***
Dinajpur	0.33	0.41	0.35	***0.57***
Gaibandha	0.51	0.61	0.26	***0.81***
Kurigram	0.49	0.78	0.17	***0.96***
Lalmonirhat	0.31	0.58	0.02	***0.83***
Nilphamari	0.32	0.62	0.08	***0.83***
Panchagarh	0.32	0.39	0.04	***0.73***
Rangpur	0.31	0.64	0.33	***0.70***
Thakurgaon	0.33	0.28	0.12	***0.62***
Bogra	0.71	0.34	0.35	***0.51***
C. Nawabganj	0.79	0.57	0.14	***0.76***
Joypurhat	0.53	0.32	0.22	***0.46***
Naogaon	0.61	0.23	0.33	***0.38***
Natore	0.60	0.46	0.21	***0.56***
Pabna	0.78	0.58	0.38	***0.64***
Rajshahi	0.79	0.36	0.45	***0.49***
Sirajganj	0.75	0.58	0.19	***0.73***

Bandarban	**0.00**	0.39	**0.00**	***0.43***
Brahmanbaria	0.45	0.42	0.29	***0.45***
Chandpur	0.94	0.29	0.39	***0.62***
Chittagong	0.54	**0.00**	**1.00**	***0.01***
Comilla	0.45	0.16	0.81	***0.05***
Cox's Bazar	0.41	0.40	0.17	***0.59***
Feni	0.78	0.24	0.42	***0.54***
Khagrachhari	0.01	0.38	0.09	***0.59***
Lakshmipur	0.89	0.12	0.23	***0.66***
Noakhali	0.94	0.36	0.43	***0.71***
Rangamati	0.11	0.50	0.13	***0.53***
Habiganj	0.53	0.29	0.13	***0.54***
Maulvibazar	0.17	0.32	0.23	***0.49***
Sunamganj	0.38	0.09	0.06	***0.48***
Sylhet	0.01	0.63	0.49	***0.53***

The results of capture fisheries vulnerability also found some North-Bengal districts and some coastal districts very highly vulnerable. Even within the very highly vulnerable districts there have different vulnerability among the various districts. For example, among the ten very highly vulnerable districts Bhola district has the highest vulnerability. Hasan *et al.* (2011) also found Bhola district vulnerable and affected by different disasters like cyclone, tidal surge, river bank erosion, salinity, accretion, flood and water logging. In this study, Bhola district is very highly exposed (Figure 8) with very high sensitivity (Figure 9) but it has low adaptive capacity (Figure 6) which made Bhola very highly vulnerable to climate variability and change. On the other hand among the low vulnerable districts of capture fisheries, the lowest vulnerability has been found in Dhaka which is moderately exposed with low sensitivity but has very high capacity to adapt. Another important phenomenon has been found that, districts adjacent to the river bank has high vulnerability. The possible reason could be that, the people of these regions are highly exposed and also have higher dependency on capture fisheries.

Table 26: Districts with various category of vulnerability to climate change on capture fisheries sector in Bangladesh.

Very High	**High**		**Moderate**	**Low**
Bhola	Bogra	Magura	Narayanganj	Gazipur
Khulna	Gopalganj	Narail	Naogaon	Dhaka
Gaibandha	Rangamati	Chandpur	Bandarban	Chittagong
Lalmonirhat	Sylhet	Thakurgaon	Jessore	Comilla
Nilphamari	Feni	Barguna	Brahmanbaria	
Satkhira	Habiganj	Chuadanga	Joypurhat	
Shariatpur	Netrakona	Pabna	Sunamganj	
Kurigram	Kishoreganj	Lakshmipur	Maulvibazar	
Patuakhali	Natore	Manikganj	Mymensingh	
C. Nawabganj	Dinajpur	Kushtia	Narsingdi	
	Jhenaidah	Jamalpur	Rajshahi	
	Munshiganj	Tangail		
	Sherpur	Noakhali		
	Cox's Bazar	Bagerhat		
	Jhalokati	Panchagarh		
	Khagrachhari	Rajbari		
	Madaripur	Sirajganj		
	Pirojpur	Faridpur		
	Barisal	Meherpur		
	Rangpur			

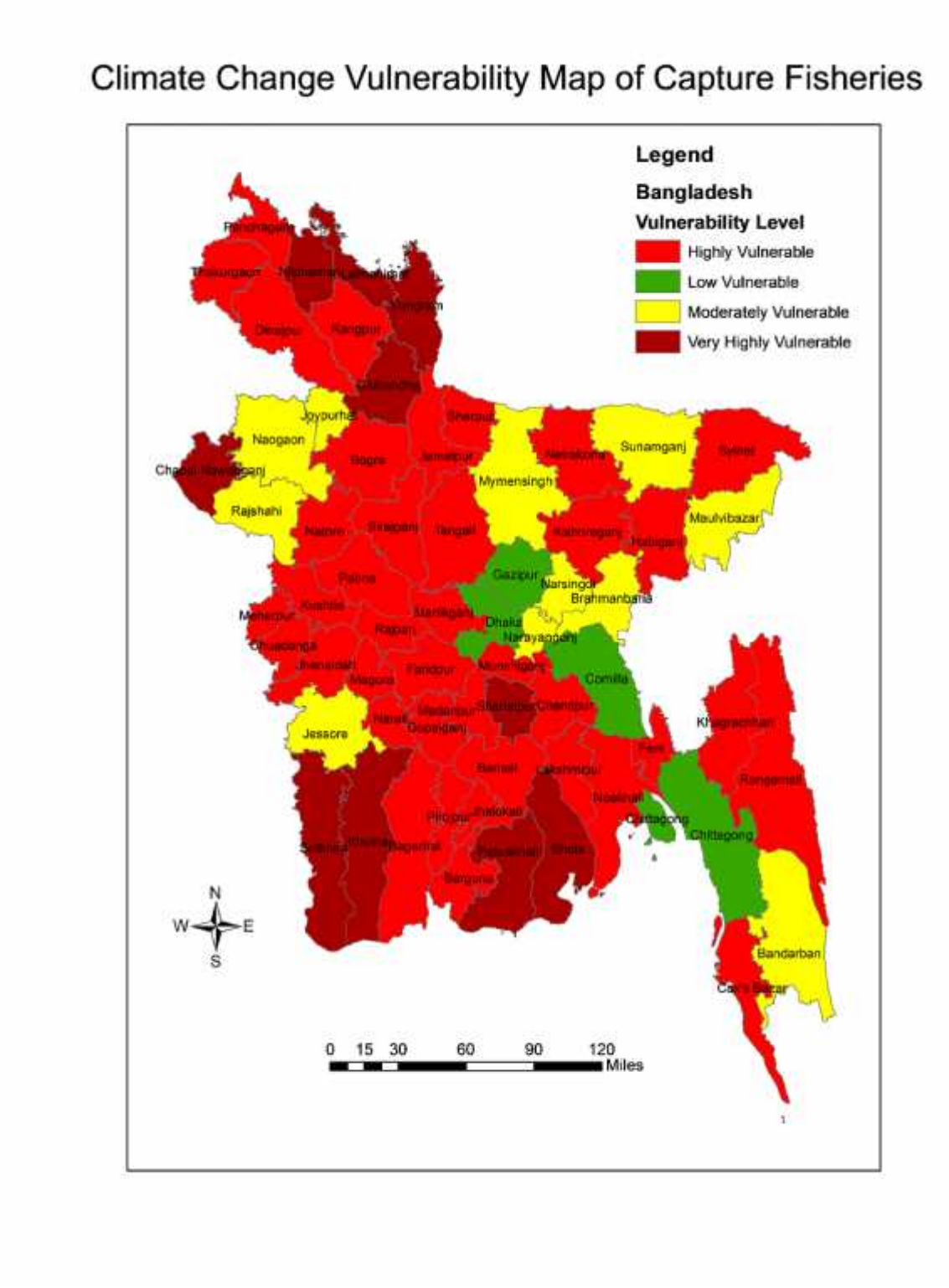


Figure10: Vulnerability of capture fisheries of Bangladesh to climate.

3.3 Vulnerability of Inland Fisheries

Like the section before (section 3.1), values of exposure, sensitivity and adaptive capacity create vulnerability of inland fisheries. Detailed explanation of exposure, sensitivity and adaptive capacity is given below.

3.3.1 Exposure

Exposure of overall inland fisheries is same as the exposure of capture fisheries. See section 3.2.1 for details.

3.3.2 Sensitivity

By districts value of sensitivity (normalized value) along with the values of the indicators (normalized) used for the calculation of sensitivity has given in Table 27. After dividing them into quartiles, it has found that, Rangamati district is very highly sensitive and Mymensingh district has the lowest sensitivity. Moreover four (4) districts has fallen in highly sensitive area. These districts are Jhenaidah, Sunamganj, Sylhet and Maulvibazar. The rest 58 districts has moderate sensitivity in overall fisheries sector. Figure 11 is showing the sensitivity map of overall fisheries by district. The detailed name of the districts has given in Table 28.

Table 27: By district sensitivity along with the value of indicators used to calculate sensitivity.

Districts	***Fish Production***	***Water area***	***Sensitivity***
Dhaka	0.87	0.02	***0.43***
Faridpur	0.96	0.02	***0.48***
Gazipur	0.92	0.02	***0.45***
Gopalganj	0.92	0.03	***0.46***
Jamalpur	0.96	0.02	***0.48***
Kishoreganj	0.91	0.10	***0.49***

Madaripur	0.98	0.01	***0.48***
Manikganj	0.97	0.01	***0.48***
Munshiganj	0.95	0.00	***0.46***
Mymensingh	0.00	0.07	***0.00***
Narayanganj	0.92	0.00	***0.44***
Narsingdi	0.96	0.01	***0.47***
Netrakona	0.86	0.13	***0.48***
Rajbari	0.97	0.02	***0.48***
Shariatpur	0.98	0.00	***0.48***
Sherpur	0.94	0.03	***0.47***
Tangail	0.92	0.04	***0.46***
Bagerhat	0.80	0.00	***0.38***
Chuadanga	0.98	0.03	***0.49***
Jessore	0.56	0.11	***0.31***
Jhenaidah	0.97	0.07	***0.50***
Khulna	0.94	0.02	***0.46***
Kushtia	0.94	0.02	***0.46***
Magura	1.00	0.01	***0.49***
Meherpur	0.99	0.02	***0.49***
Narail	0.98	0.02	***0.48***
Satkhira	0.80	0.02	***0.39***
Barguna	0.97	0.00	***0.47***
Barisal	0.92	0.03	***0.46***
Bhola	0.92	0.00	***0.44***
Jhalokati	0.98	0.00	***0.48***
Patuakhali	0.95	0.00	***0.46***
Pirojpur	0.98	0.00	***0.47***
Dinajpur	0.96	0.03	***0.48***
Gaibandha	0.93	0.02	***0.46***
Kurigram	0.98	0.03	***0.49***
Lalmonirhat	0.99	0.01	***0.48***
Nilphamari	0.98	0.02	***0.49***
Panchagarh	0.98	0.00	***0.48***
Rangpur	0.96	0.04	***0.48***
Thakurgaon	0.98	0.03	***0.49***
Bogra	0.86	0.02	***0.42***
Nawabganj	0.98	0.04	***0.49***
Joypurhat	0.96	0.00	***0.46***
Naogaon	0.84	0.08	***0.44***
Natore	0.96	0.02	***0.47***
Pabna	0.90	0.03	***0.45***
Rajshahi	0.83	0.09	***0.44***
Sirajganj	0.92	0.01	***0.45***

Bandarban	1.00	0.00	***0.48***
Brahmanbaria	0.95	0.02	***0.47***
Chandpur	0.86	0.01	***0.42***
Chittagong	0.87	0.00	***0.42***
Comilla	0.68	0.01	***0.32***
Cox's Bazar	0.94	0.02	***0.46***
Feni	0.91	0.00	***0.44***
Khagrachhari	0.99	0.01	***0.49***
Lakshmipur	0.91	0.00	***0.44***
Noakhali	0.80	0.00	***0.38***
Rangamati	0.99	1.00	***1***
Habiganj	0.90	0.06	***0.46***
Maulvibazar	0.90	0.16	***0.51***
Sunamganj	0.81	0.50	***0.64***
Sylhet	0.91	0.13	***0.51***

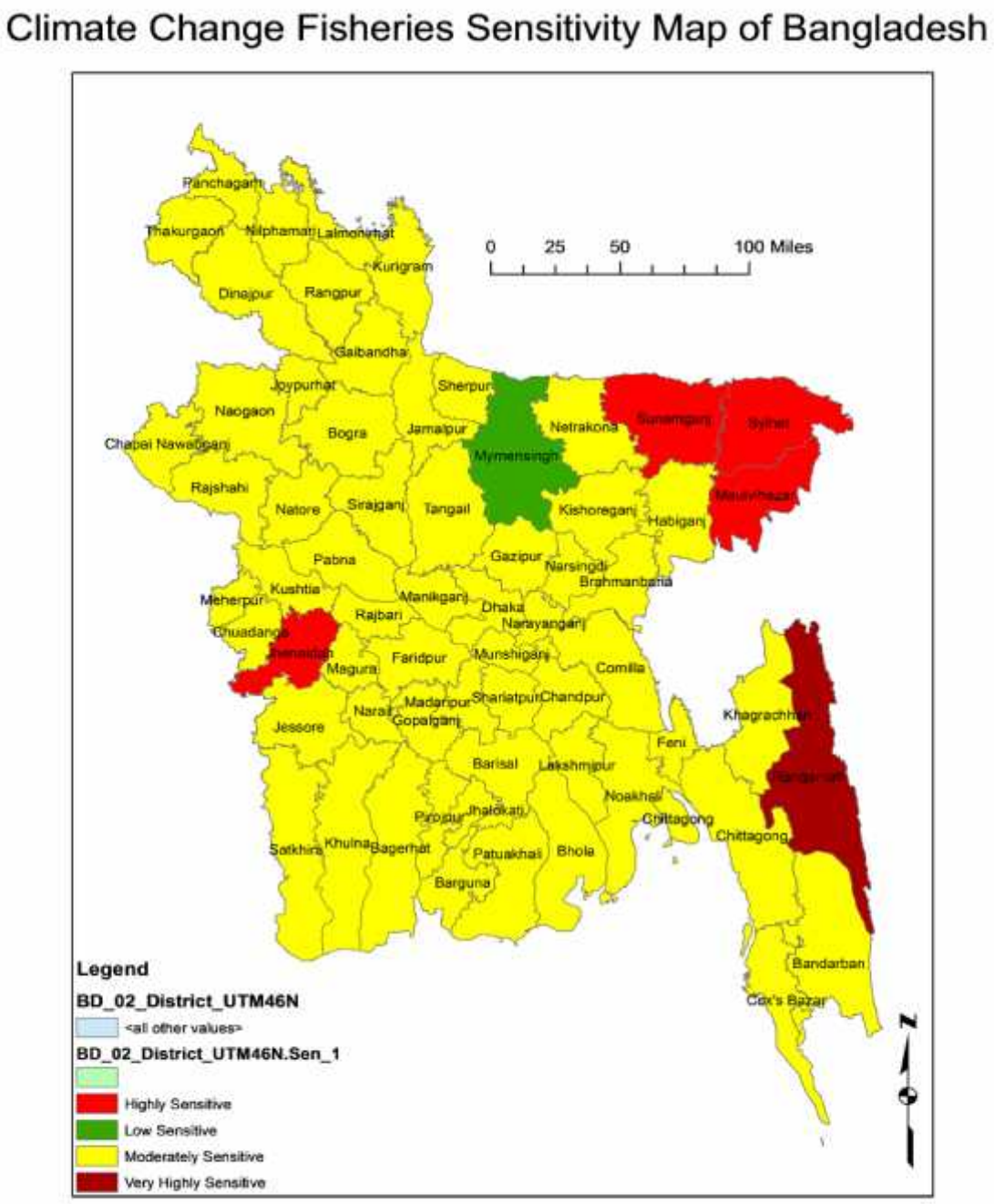


Figure 11: Sensitivity of fisheries of Bangladesh to climate.

Table 28: Districts with various category of sensitivity to climate change.

Very Highly Sensitive	**Highly Sensitive**	**Moderately Sensitive**			**Low Sensitive**
Rangamati	Jhenaidah	Dhaka	Lakshmipur	Patuakhali	Mymensingh
	Sunamganj	Faridpur	Noakhali	Pirojpur	
	Sylhet	Gazipur	Rangamati	Dinajpur	
	Maulvibazar	Gopalganj	Bogra	Gaibandha	
		Jamalpur	Joypurhat	Kurigram	
		Kishoreganj	Naogaon	Lalmonirhat	
		Madaripur	Natore	Nilphamari	
		Manikganj	C. Nawabganj	Panchagarh	
		Munshiganj	Pabna	Thakurgaon	
		Narayanganj	Rajshahi	Habiganj	
		Narsingdi	Sirajganj	Cox's Bazar	
		Netrakona	Bagerhat	Feni	
		Rajbari	Chuadanga	Khagrachhari	
		Shariatpur	Jessore	Barisal	
		Sherpur	Khulna	Bhola	
		Tangail	Kushtia	Jhalokati	
		Bandarban	Magura	Comilla	
		Brahmanbaria	Meherpur	Barguna	
		Chandpur	Narail		
		Chittagong	Satkhira		

3.3.3 Adaptive Capacity

Adaptive capacity for 64 districts are same as culture and capture fisheries. See section 3.1.3 (adaptive capacity of culture fisheries) for details.

3.3.4 Vulnerability

Table 29 represents the values of vulnerability (normalized) along with the values of exposure, sensitivity and adaptive capacity (all are normalized value) of 64 districts of Bangladesh. Taking into account the values of exposure, sensitivity and adaptive capacity, the result of vulnerability is calculated in additive (formula 4) method and after dividing the normalized value into quartiles, it has given Figure 12 as the vulnerability map of fisheries of Bangladesh. The map has showed that sixteen (16)districts has very high vulnerability. Those districts are Rangamati, Patuakhali, Bhola, Noakhali, Lakshmipur, Chandpur, Shariatpur, Rajbari, Chapai Nawabganj, Sunamganj, Gaibandha, Kurigram, Lalmonirhat, Nilphamari, Panchagarh and Thakurgaon. All the district either is very highly exposed or have very high sensitivity with a low adaptive capacity which finally made these district very highly vulnerable. Another study also found that different components of vulnerability affects fisheries in varied ways because various levels of exposure and highest sensitivity does not always lead highest fisheries vulnerability (Islam *et al.* 2014). For example, Shariatpur district has very high exposure value with moderate sensitivity, but its adaptive capacity is very low which made this district very highly vulnerable. On the contrary Dhaka, Comilla, Mymensingh, Jessore and Chittagonghas low vulnerability because of low dependency (sensitivity) and high adaptive capacity. But the highest adaptive capacity does not always result in the lowest fisheries vulnerability (Islam *et al.* 2014).On the other hand thirty-four (34) districts has high vulnerabilityand the rest nine (9) districts has moderate vulnerability. The name of the districts along with their category of vulnerability is given in Table 30.A study of Islam *et al.*(2014) found that between the two fishing communities of Barguna and Cox's Bazar (southern coastal Bangladesh), fishing community of Barguna district have higher livelihood vulnerability. Agrawala *et al.* (2003) found these two districts more affected by climatic phenomenon such as cyclones, tidal fluctuations and salinity

intrusion than other coastal areas of Bangladesh. In this study Barguna is highly exposed to climatic variables but Cox's Bazar district is moderately exposed. The possible reason of these dissimilarity could be the difference of exposure indicators used in these two study.Another case study has found Bhola district vulnerable to climate change and affected by different disasters like cyclone, tidal surge, river bank erosion, salinity, accretion, flood and water logging (Hasan *et al.* 2011). This study also has found Bhola district very highly exposed to climatic variables and thus very highly vulnerable because of low adaptive capacity.

Table 29: Values of vulnerability along with the values of exposure, sensitivity and adaptive capacity of 64 districts of Bangladesh.

Districts	***Exposure***	***Sensitivity***	***Adaptive Capacity***	***Vulnerability***
Dhaka	0.36	0.43	**1.00**	***0.00***
Faridpur	0.54	0.48	0.24	***0.68***
Gazipur	0.36	0.45	0.59	***0.30***
Gopalganj	0.31	0.46	0.27	***0.49***
Jamalpur	0.54	0.48	0.31	***0.63***
Kishoreganj	0.37	0.49	0.27	***0.55***
Madaripur	0.31	0.48	0.13	***0.60***
Manikganj	0.36	0.48	0.13	***0.63***
Munshiganj	0.56	0.46	0.32	***0.64***
Mymensingh	0.37	**0.00**	0.51	***0.04***
Narayanganj	0.36	0.44	0.53	***0.34***
Narsingdi	0.36	0.47	0.33	***0.49***
Netrakona	0.37	0.48	0.13	***0.64***
Rajbari	0.54	0.48	0.12	***0.77***
Shariatpur	0.88	0.48	0.13	***1.00***
Sherpur	0.37	0.47	0.12	***0.64***
Tangail	0.56	0.46	0.40	***0.58***
Bagerhat	0.45	0.38	0.36	***0.48***
Chuadanga	0.37	0.49	0.18	***0.62***
Jessore	0.37	0.31	0.55	***0.23***
Jhenaidah	0.37	0.50	0.36	***0.50***
Khulna	0.76	0.46	0.65	***0.55***
Kushtia	0.59	0.46	0.34	***0.64***
Magura	0.37	0.49	0.18	***0.62***

Meherpur	0.37	0.49	0.19	***0.61***
Narail	0.37	0.48	0.16	***0.63***
Satkhira	0.57	0.39	0.32	***0.59***
Barguna	0.51	0.47	0.20	***0.69***
Barisal	0.74	0.46	0.58	***0.57***
Bhola	0.84	0.44	0.18	***0.91***
Jhalokati	0.50	0.48	0.28	***0.62***
Patuakhali	0.79	0.46	0.26	***0.83***
Pirojpur	0.43	0.47	0.28	***0.58***
Dinajpur	0.60	0.48	0.35	***0.65***
Gaibandha	0.77	0.46	0.26	***0.82***
Kurigram	0.80	0.49	0.17	***0.92***
Lalmonirhat	0.60	0.48	0.02	***0.88***
Nilphamari	0.61	0.49	0.08	***0.85***
Panchagarh	0.61	0.48	0.04	***0.87***
Rangpur	0.60	0.48	0.33	***0.67***
Thakurgaon	0.60	0.49	0.12	***0.82***
Bogra	0.54	0.42	0.35	***0.57***
C. Nawabganj	0.59	0.49	0.14	***0.81***
Joypurhat	0.34	0.46	0.22	***0.55***
Naogaon	0.39	0.44	0.33	***0.49***
Natore	0.39	0.47	0.21	***0.60***
Pabna	0.59	0.45	0.38	***0.61***
Rajshahi	0.59	0.44	0.45	***0.55***
Sirajganj	0.57	0.45	0.19	***0.72***
Bandarban	**0.00**	0.48	**0.00**	***0.48***
Brahmanbaria	0.30	0.47	0.29	***0.48***
Chandpur	0.84	0.42	0.39	***0.75***
Chittagong	0.57	0.42	**1.00**	***0.14***
Comilla	0.30	0.32	0.81	***0.02***
Cox's Bazar	0.46	0.46	0.17	***0.67***
Feni	0.79	0.44	0.42	***0.70***
Khagrachhari	0.40	0.49	0.09	***0.70***
Lakshmipur	0.94	0.44	0.23	***0.94***
Noakhali	**1.00**	0.38	0.43	***0.81***
Rangamati	0.20	**1.00**	0.13	***0.89***
Habiganj	0.42	0.46	0.13	***0.67***
Maulvibazar	0.42	0.51	0.23	***0.64***
Sunamganj	0.45	0.64	0.06	***0.86***
Sylhet	0.45	0.51	0.49	***0.47***

Climate Change Fisheries Vulnerability Map of Bangladesh

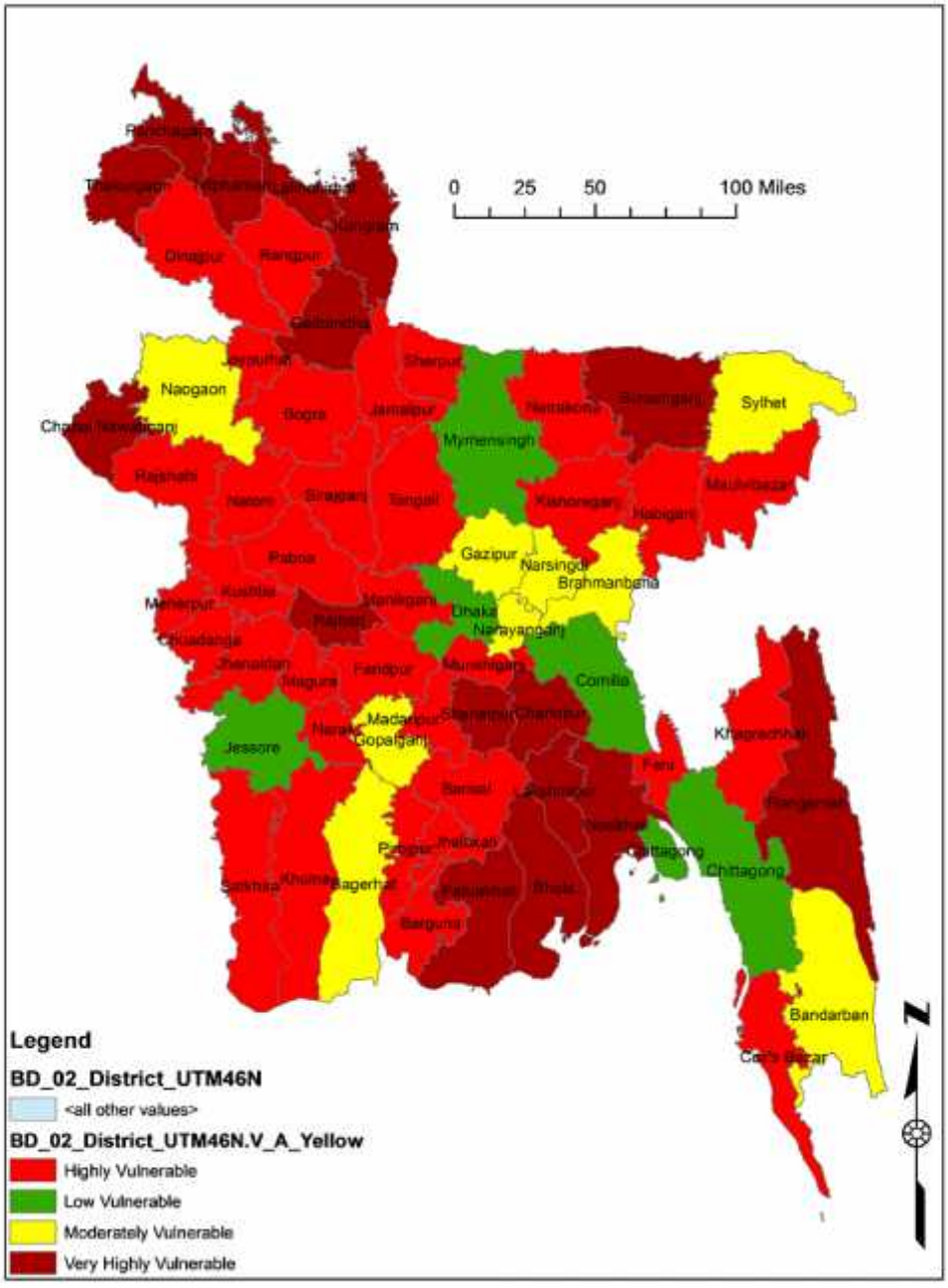


Figure 12: Vulnerability of Fisheries of Bangladesh to climate.

Table 30: Districts with various category of vulnerability to climate change.

Very Highly Vulnerable	**Highly Vulnerable**		**Moderately Vulnerable**	**Low Vulnerable**
Rangamati	Dinajpur	Faridpur	Naogaon	Dhaka
Patuakhali	Rangpur	Manikganj	Sylhet	Comilla
Bhola	Joypurhat	Madaripur	Gazipur	Mymensingh
Noakhali	Bogra	Narail	Narsingdi	Jessore
Lakshmipur	Sherpur	Satkhira	Narayanganj	Chittagong
Chandpur	Jamalpur	Khulna	Brahmanbaria	
Shariatpur	Rajshahi	Barisal	Gopalganj	
Rajbari	Natore	Pirojpur	Bagerhat	
C. Nawabganj	Sirajganj	Jhalokati	Bandarban	
Sunamganj	Tangail	Barguna		
Gaibandha	Pabna	Feni		
Kurigram	Meherpur	Khagrachhari		
Lalmonirhat	Kushtia	Cox's Bazar		
Nilphamari	Chuadanga	Netrakona		
Panchagarh	Jhenaidah	Kishoreganj		
Thakurgaon	Magura	Habiganj		
	Maulvibazar			

However, Shahid and Behrawan (2008) has analyzed the drought occurrences at different categories and time steps and found that northern and northwestern parts of the country are most prone to severe and very severe droughts. In the southern part of the country, moderate droughts occur. But the central part of the western Bangladesh has moderate prone for both moderate and severe droughts but less prone to very severe droughts. On the other hand, this study has found the northwestern and southern Bangladesh very highly vulnerable to climate

change in fisheries. As there is difference between the two studies, dissimilarity is very natural.

In summary, this study found that for fisheries (i.e. culture, capture and overall fisheries), North-Bengal and coastal districts are very highly vulnerable to climate variability and change. Moreover, districts adjacent to the river bank are highly vulnerable. And for most cases the divisional districts have low vulnerability because of very high/high adaptive capacity and low/moderate sensitivity.

Chapter 4: Conclusions

The objectives of this study was to analyze vulnerability of culture, capture and overall fisheries sector to climate variability and change in 64 districts of Bangladesh using composite vulnerability index approach.

This study has showed that for overall fisheries sector, sixteen districts (i.e. Rangamati, Patuakhali, Bhola, Noakhali, Lakshmipur, Chandpur, Rajbari, Shariatpur, Chapai Nawabganj, Sunamganj, Gaibandha, Kurigram, Lalmonirhat, Nilphamari, Panchagarh and Thakurgaon) are very highly vulnerable. This vulnerability has been the combined effect of exposure, sensitivity and adaptive capacity. Most of these districts has been very highly/highly exposed to climate variables. Although these districts have moderate sensitivity (except Rangamati and Sunamganj), they have become very highly vulnerable because of low/moderate adaptive capacity. On the other hand, Dhaka, Comilla, Mymensingh, Jessore and Chittagong districts have low vulnerability to climate change only because of very high/high adaptive capacity. Also their exposure and sensitivity level was low to moderate (except Chittagong).

The sectorial vulnerability (culture and capture) of different districts also vary according to their exposure, sensitivity and adaptive capacity level. Because of different level of exposure, the highest sensitivity does not always lead to the highest vulnerability, similarly the highest adaptive capacity does not always result to lowest vulnerability. So vulnerability of a certain district is highly context-dependent. A large number of factors influence vulnerability of a district.

This study also found that, coastal district, districts from the north side of Bangladesh and districts adjacent to the river bank are very highly/highly vulnerable to climatic variables as the people of these regions are directly involved in fisheries (specially capture fisheries).

4.1 Implications of the Research

As this study hasidentified district level vulnerability of fisheries of Bangladesh,the findings of this study will allow the policymakers to easily identify the most vulnerable districts and takes necessary step to decrease the vulnerability and increase the adaptive capacity in facing climate change. Bangladesh Government have some sources of fund for climate change mitigation and adaptation (i.e. Bangladesh Climate change Trust Fund (BCCTF) and Bangladesh Climate Change Resilient Fund (BCCRF)). The aim of thistwo fund is to reduce the vulnerability caused by the adverse effects of climate change and building resilience to the effect of climate change. Utilizing the findings of the study, the policymaker can easily understand where to spend the money in the context of fisheries sector. Moreover, others such as NGOs donors can target in the most vulnerable districts at field level to reduce the vulnerability. Finally the very highly vulnerable districts can learn from the low vulnerable districts to reduce the level of vulnerability.

4.2 Limitations and Future Research

Although in the context of fisheries and climate change, this study has determined the differential level of vulnerability at different districts in rigorous way following state-of-the art methodology, it is not out of criticism. In some cases, deficiency of district level data was prominent. Almost all of the organizations produce mostly national level data. Future study should use more district level data to determine the level of vulnerability.

However, this research provides an important starting point for directing future research into the vulnerability of fisheries to climate change. This study has found sixteen districts very highly vulnerable to climate change. But the specific reasons of very high or low of vulnerability have not been assessed at the field level due to academic time constraints. So the next topic of research could be assessing the reasons of very high or low vulnerability at the field level. Moreover, this study did not specify which habitat is highly vulnerable to

climate change. So one can easily assess the fish habitat level vulnerability. Another important question arise is that which species is vulnerable to climate change. As this study was by district vulnerability of fisheries sector, so marine fisheries was not included in this research. So vulnerability of the Bay of Bengal fisheries can be an excellent research topic for future researchers.

References

ADAMS, W.M. and MORTIMORE, M.J. 1997. Agricultural Intensification and Flexibility in the Nigerian Sahel. *Geogra J*. **163(2)**: 50–160.

ADGER, W.N. 1999. Social vulnerability to climate change and extremes in coastal Vietnam.*World Dev*.**27(2)**: 249-269.

ADGER, W.N. 2006. Vulnerability. *Glob. Environ. Chang.***16(3)**: 268–281.

AGRAWALA, S., OTA, T., AHMED, A.U., SMITH, J. and VANAALST, M. 2003. Development and climate change in Bangladesh: Focus on coastal flooding and the Sundarbans. Paris: Organisation for Economic Co-operation and Development. *OECOD* France.

AHMED, A.U., SIDDIQI, N.A. and CHOUDHURI, R.A. 1999. Vulnerability of Forest Ecosystem of Bangladesh to Climate Change. In Huq, S., Karim, Z., Asaduzzaman, M., Mahtab, F. (ed.). *Vulnerability and adaptation to Climate Change for Bangladesh.* Pp. 93-113. Kluwer Academic publishers, The Netherlands.

AHMED, N. and DIANA, J.S. 2015. Coastal to inland: Expansion of prawn farming for adaptation to climate change in Bangladesh. *Aquacult Res*.**2**: 67–76.

ALAM, M., NISHAT, A. and SIDDIQUI, S.M. 1999. Water Resources Vulnerability to Climate Change with Special Reference to Inundation. In Huq, S., Karim, Z., Asaduzzaman, M., Mahtab, F. (ed.). *Vulnerability and adaptation to Climate Change for Bangladesh.* Kluwer Academic publishers, The Netherlands, 21-38pp.

ALBERINI, A., CHIABAI, and MUEHLENBACHS, L. 2005. Using Expert Judgement to Assess Adaptive Capacity to Climate Change: Evidence from Conjoint Choice Survey. *SIEV*.

ALI, M.Y. 1999. Fish Resources Vulnerability and Adaptation to Climate Change in Bangladesh. In Huq, S., Karim, Z., Asaduzzaman, M., Mahtab, F. (ed.). *Vulnerability and adaptation to Climate Change for Bangladesh.* Kluwer Academic publishers, The

Netherlands, 21-38pp.

ALLISON, E.H., ADGER, W.N., BADJECK, M.C., BROWN, K., CONWAY, D., DULVY, N.K., HALLS, A. and PERRY, A. 2005. Effects of climate change on the sustainability of capture and enhancement fisheries important to the poor: analysis of the vulnerability and adaptability of fisherfolk living in poverty. *Final Technical Report.*

ALLISON, E.H., PERRY, A.L., BADJECK, M.C., NEIL A.W., BROWN, K., CONWAY, D., HALLS, A.S., PILLING, G.M., REYNOLDS, J.D., ANDREW, N.L. and DULVY, N.K. 2009. Vulnerability of national economies to the impacts of climate change on fisheries.*Fish Fish***10(2)**: 173–196.

ANTWI-AGYEI, P., FRASER, E.D.G., DOUGILL, A.J., STRINGER, L.C. and SIMELTON, E. 2012. Mapping the vulnerability of crop production to drought n Ghana using rainfall, yield and socioeconomic data. Appl. Geogr.**32**: 324-334.

BADJECK, M.C., ALLISON, E.D., HALLS, A.H. and DULVY, N.K. 2010. Impacts of climate variabiity and change on fishery-based livelihoods. *Mar. Policy* **34(3)**: 375-383.

BARANGE, M. 2002. Influence of climate variability and change on the structure, dynamics and exploitation of marine ecosystems. *Environ. Sci. Technol.***17(2002)**:57–82.

BBS. 2013. Bangladesh Bureau of Statistics, Statistics and Information Division, Ministry of Planning. 562pp.

BEAUGRAND, G., REID, P.C., IBAÑEZ, F., LINDLEY, J.A. and EDWARDS, M. 2002. Reorganization of North Atlantic marine copepod biodiversity and climate. *Science* **296(5573)**: 1692–1694.

BMD. 2015. Personal Collection. Bangladesh Meteorological Department. Agargaon, Dhaka.

BRANDER, K. 2007. Global Fish Production and Climate Change. *PNAS***104**: 19709–19714.

BRANDER, K. 2010. Impacts of climate change on fisheries. *J. Mar. Syst.***79(3-4)**: 389–402.

BROOKS, N., ADGER, W.N. and KELLY, P.M. 2005. The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation. *Glob. Environ. Chang.***15(2):** 151–163.

BROUWER, R., AKTER, S., BRANDER, L. and HAQUE, E. 2007. Socioeconomic vulnerability and adaptation to environmental risk: A case study of climate change and flooding in Bangladesh.*Risk Anal.* **27**: 313-326.

CARPENTER, S.R., FISHER, N.B. AND GRIMM, J.F.K. 1992. Global Change and Freshwater systems. *Annu. Rev. Ecol. Syst.***23**: 119–139.

CEGIS. 2015. Personal Collection. Center for Environmental and Geographic Information Services. Gulshan-1, Dhaka.

CHEUNG, W.W.L., LAM, V.W.Y., SARMIENTO, J.L., KEARNEY, K., WASTON, R. and PAULY, D. 2009. Projecting global marine biodiversity impacts under climate change scenario. *Fish Fish***10**: 235-251.

COCHRANE, K., DE YOUNG, C., SOTO, D. and BAHRI, T. 2009. Climate change implications for fisheries and aquaculture: overview of current scientific knowledge. *FAO Fisheries and Aquaculture Technical Paper.* No. 530. Rome, FAO. 212pp.

CUSHING, D.H. 1982. *Climate and Fisheries,* London, Academic Press.

CUTTER, S.L., BARNES, L., BERRY, M., BURTON, C., EVANS, E., TATE, E. and WEBB, J. 2008. A place-based model for understanding community resilience to natural disasters. *Glob. Environ. Chang.* **18:** 598-606.

CZÚCZ, B., TORDA, G., MOLNÁR, Z., HORVÁTH, F., BOTTA-DUKÁT, Z. and KRÖEL-DULAY, G. 2009. A spatially explicit, indicator-based methodology for quantifying the vulnerability and adaptability of natural ecosystems. *In:* LEAL, F.W. and MANNKE, F. (ed.). YAN, J. 2007. *Interdisciplinary Aspects of Climate Change.* Frankfurt am Main: Peter Lang.

DASGUPTA, S., LAPLANTE, B., MEISNER, C.M., WHEELER, D. and YAN, J. 2007. The Impact of Sea Level Rise on Developing Countries: A Comparative Analysis. *PRWP* 4136.

DASGUPTA, S., HUQ, M., KHAN, Z.H., AHMED, M.M.Z., MUKHERJEE, N., KHAN, M. F. and PANDEY, K. 2014. Cyclones in a changing climate: the case of Bangladesh. *Clim. and Dev.***6(2)**: 96–110.

DAVID, S. 1997. Intra-household processes and the adoption of hedgerow intercropping.*Agric. Human Values***15**: 31-42.

DAW, T., ADGER, W.N., BROWN, K. and BADJECK, M.C. 2009. Climate change and capture Fisheries: potential impacts, adaptation and mitigation. In K. Cochrane, C. De Young, D. Soto and T. Bahri (ed.). *Cimate change implications for fisheries and aquaculture: overview of current acientific knowledge*. FAO Fisheries and Aquaculture Technical Paper. No. 530 FAO pp. 107-150.

DOF. 2012. *National Fisheries Week 2012*, Department of Fisheries, Government of Bangladesh.

DRINKWATER, K.F., BEAUGRAND, G., KAERIYAMA, M., KIM, S., OTTERSEN, G., PERRY, R.I., PORTNER, H.O., POLOVINA, J.J., and TAKASUKA, A. 2010. On the processes linking climate to ecosystem changes. *J. Mar. Syst.***79**: 374-388.

DRINKWATER, K., FROMENTIN, J.M., HARE, S.R., OTTERSEN, G., PERRY, R.I., ROY, C., VANDERLINGEN, C.D. and WERNER, F. 2006. Climate variability, fish and fisheries.*J. Climate***19**: 5009–5030.

DULVY, N.K., ROGERS, S.I., JENNINGS, S., STELZENMU¨ LLER, V., DYE, S.R. and SKJOLDAL, H.R. 2008. Climate change and deepening of the North Sea fish assemblage: a biotic indicator of regional warming. *J. Appl. Ecol.***45**: 1029–1039.

EAKIN, H. 2005. Institutional change, climate risk, and rural vulnerability: Cases from Central Mexico. *World Dev.***33:**1923-1938.

FANG, Y., FAN, J. and SONG, M. 2014. Sensitivity of livelihood strategy to livelihood capital in mountain areas: Empirical analysis based on different settlements in the uper reaches of the Minjiang River, China. *Ecol. Indic.***38**: 225-235.

FAO. 1996. Handbook on Fish Culture. *Annex III.*

FAO. 2008. Climate change for fisheries and aquaculture. Technical background document

from the Expert Consultation, 7 to 9 April 2008, FAO, Rome. Paper presented at 'Climate Change, Energy and Food'.

FAO. 2012. *The state of world fisheries and aquaculture 2012*. Rome: Fisheries and Auaculture Department, Food and Agriculture Organization of the United Nations.

FICKE, A.D., MYRICK, Æ.C.A. and HANSEN, L.J. 2007. Potential impacts of global climate change on freshwater fisheries. *Rew. Fish. Biol. Fisher.***17(4)**: 581-613.

FHS, C. 2006. Estimation of rainfall elasticity of streamflow in Australia. *Hydrol. Sci. J.***51(4)**: 613–625.

FICKE, A.D., MYRICK, Æ.C.A. and HANSEN, L.J. 2007. Potential impacts of global climate change on freshwater fisheries. *Rew. Fish Biol. Fisher***17(4)**: 581-613.

FISCHER, G., SHAH, M., TUBIELLO, F.N. and VAN VELHUIZEN, H. 2005. Socioeconimic and climate change impacts on agriculture: An integrated assessment, 1990-2080.*Philos. Trans. R. Soc. Lond. B. Biol. Sci.***360**: 2067-2083.

FORD, J.D., SMIT, B. and WANDEL, J. 2006. Vulnerability to climate change in the Arctic: A case study from Arctic Bay, Canada. *Glob. Environ. Chang*. **16(2)**: 145–160.

FRASER, E.G. 2007. Travelling in antique lands: Using past famines to develop an adaptability/resilience framework to identify food systems vulnerable to climate change.*Clim. Change* **83**: 495-514.

FRSS. 2003. *Fisheries Statistical Yearbook of Bangladesh.* Fisheries Resources Survey System (FRSS). Department of Fisheries, Bangladesh. **19**: 41pp.

FRSS. 2004. *Fisheries Statistical Yearbook of Bangladesh*. Fisheries Resources Survey System (FRSS). Department of Fisheries, Bangladesh. **20**: 41pp.

FRSS. 2005. *Fisheries Statistical Yearbook of Bangladesh*. Fisheries Resources Survey System (FRSS). Department of Fisheries, Bangladesh. **21**: 41pp.

FRSS. 2006. *Fisheries Statistical Yearbook of Bangladesh.* Fisheries Resources Survey System (FRSS). Department of Fisheries, Bangladesh. **22**: 42pp.

FRSS. 2007. *Fisheries Statistical Yearbook of Bangladesh.* Fisheries Resources Survey

System (FRSS). Department of Fisheries, Bangladesh. **23**: 42pp.

FRSS. 2008. *Fisheries Statistical Yearbook of Bangladesh.* Fisheries Resources Survey System (FRSS). Department of Fisheries, Bangladesh. **24**: 42pp.

FRSS. 2009. *Fisheries Statistical Yearbook of Bangladesh.* Fisheries Resources Survey System (FRSS). Department of Fisheries, Bangladesh. **25**: 42pp.

FRSS. 2010. *Fisheries Statistical Yearbook of Bangladesh.* Fisheries Resources Survey System (FRSS). Department of Fisheries, Bangladesh. **26**: 41pp.

FRSS. 2011. *Fisheries Statistical Yearbook of Bangladesh*. Fisheries Resources Survey System (FRSS). Department of Fisheries, Bangladesh. **27**: 43pp.

FRSS. 2012. *Fisheries Statistical Yearbook of Bangladesh.* Fisheries Resources Survey System (FRSS). Department of Fisheries, Bangladesh. **28**: 46pp.

FRSS. 2013. *Fisheries Statistical Yearbook of Bangladesh*. Fisheries Resources Survey System (FRSS). Department of Fisheries, Bangladesh. **29**: 44pp.

FRSS. 2014. *Fisheries Statistical Yearbook of Bangladesh.* Fisheries Resources Survey System (FRSS). Department of Fisheries, Bangladesh. **30**: 52pp.

FRSS. 2015. *Fisheries Statistical Report of Bangladesh.* Fisheries Resources Survey System (FRSS), Department of Fisheries, Bangladesh. **31**: 57pp.

GLANTZ, M.H. and FEINGOLD, L.E. 1992. Climate variability, climate change and fisheries: A summary. *In:* Glantz, M.H. (ed.) *Climate Variability, Climate change, and Fisheries.* Cambridge University Press.

GLEASON, K. L. 2008. Indian Ocean Basins in "State of the Climate in 2007. *BMAS* **89**: 75–S77.

GOODWIN, N.R. 2003. Five kinds of capital: Usefull concepts for sustanable development. Global development and environment institute. Working paper no. 03-07.

GROISMAN, P.Y., KARL, T.R., EASTERLING, D.R., KNIGHT R.W., JAMESON P.F., HENNESSY, K.J., SUPPIAH, R., PAGE, C.M., WIBIG, J., FORTUNIAK, K. and RAZUVAEV, V.N. 1999. Changes in the probability of heavy precipitation: important

indicators of climatic change. *Clim. Chang.***42**: 243–283.

HADDAD, B.M. 2005. Ranking the adaptive capacity of nations to climate change when socio-political goals are explicit. *Glob. Environ. Chang.***15(2)**: 165–176

HAJKOWICZ, S. 2006. Multi-environmental index construction. *Ecol. Econ.* **57**: 122-139.

HANDMER, J.W., DOVERS, S. and DOWNING, T.E. 1999. Societal Vulnerability to Climate Change and Variability. *Mitig. Adapt. Strat. Gl.***4(3)**: 267–281.

HASAN, M.K., HASAN, M.K. and HASAN, M.K. 2011. Impact of Climate Change and Variability on Fisher Livelihoods of Coastal Communities : A Study on Dhalchar at Bhola District of Bangladesh. *OCS*1–9.

IFAD 2008. Poverty and Climate Change: Reducing the Vulnerability of the Poor through Adaptation.

IPCC, 2001. Climate change 2001: Impacts, Adaptation and Vulnerability: Contribution of working group II to the third assessment report of the Intergovernmental Panel on Climate Change. In: McCarthy JJ, Canziani OF, Leary NA, Dokken DJ, White KS (ed.). Cambridge University Press, Cambridge.

IPCC, 2007. Climate Change 2007: The Physical Science Basis.*Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, In:* Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignor, M. and Miller, H.L. (ed.). Cambridge, Cambridge University Press.

IPCC 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability.*Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, In:* Parry, M.L., Canziani, O.F., Palutikof, J.P., Van Der Linden, P.J. and Hanson, C.E. (ed.). Cambridge, Cambridge University Press.

IPCC 2013. Climate Change 2013: The Physical Science Basis. Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. In: Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (ed.). Cambridge, Cambridge University Press.

IPCC 2014: Summary for policymakers. 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* [Field, C.B., 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. Mastrangrea, and L.L.White (ed.). Cambridge, Cambridge University Press.

ISKANDER, S.M., RAJIB, M.A. and RAHAMAN, M.M. 2014. Trending Regional Precipitation Distribution and Intensity: Use of Climatic Indices. *ACS***4**: 385-393.

ISLAM, M.A. 2014. Socio-economic Effects of Climate Change on Freshwater Fisheries in Bangladesh: A Case Study of Gajnar Beel. *J. Appl. Sci. Eng.***(1)**: 1–5.

ISLAM, M.M., SALLU, S., HUBACEK, K. and PAAVOLA, J. 2014. Vulnerability of fishery-based livelihoods to the impacts of climate variability and change: Insights from coastal Bangladesh. *Reg. Environ. Change***14(1)**: 281–294.

KHONDKER, B.H. and MAHZAB, M.M. Undated. Lagging Districts Development. **1000**: 1–61.

KIBRIA, G. 2015. Climate Change Impacts , Actions and Programs (Adaptation and Mitigation) for a Most Vulnerable. September: 1–6.

KWON, D. 2009. Human capital and its measurement. The 3rd OECD World Forum on 'Statistics, Knowledge and Policy'. Busan, Korea.

LEHODEY, P., ALHEIT, J., BARANGE, M., BAUMGARTNER, T., BEAUGRAND, G., DRINKWATER, K., FROMENTIN, J.M., HARE, S.R., OTTERSEN, G., RERRY, R.I., ROY, C. LINGEN, C.D.V.D. and WERNER, F. 2006. Climate variability, fish and fisheries. *J. Climate***19**: 5009–5030.

MAB 2009. *Fisheries and Aquaculture in a Changing Climate*. FAO, Rome, Italy. 6 pp.

MACUSI, E.D. ABREO, N.A.S., CUENCA, G.C. and RANARA, C.T.M. 2015. The Potential Impacts of Climate Change on Freshwater Fish, Fish Culture and Fishing Communities. *JNS***14(2)**: 1689–1699.

MCCLANAHAN, T.R., CINNER, J.E., MAINA, J., GRAHAM, N.A.J., DAW, T.M., STEAD, S.M., WAMUKOTA, A., BROWN, K., ATEWEBERHAN, M., VENUS, V. and POLUNIN, N.V.C. 2008.Conservation action in a changing climate.*Conserv. Lett.***1**: 53-59.

MET OFFICE 2011. *Climate: Observations, projections and impacts-Bangladesh*. Met Office Hadley Centre. Department of Energy and Climate Change, United Kingdom.

MOEF. 2005. Ministry of Environment and Forest. Government of the People's Republic of Bangladesh.

MORGAN, I.J., MCDONALD, D.G. and WOOD, C.M. 2001. The cost of living for freshwater fish in a warmer, more polluted world. *Glob. Chang. Biol.***7**: 345-355

MUSTAFA, M.G. 2010. Climate Change Implications for Fisheries and Aquaculture in Bangladesh : A Review Submitted By : Group-11 Institute of Water and Flood Management (IWFM). March.

NICHOLLS, R.J. 2003. An Expert Assessment of Storm Surge "Hotspot". *Interim Re.*

PAAVOLA, J. 2008. Livelihoods, vulnerability and adaptation to climate change in Morogoro, Tanzania. *Environ. Sci. Policy***11(7)**: 642–654

PARMESAN, C. and YOHE, G. 2003. A globally coherent fingerprint of climate change impacts across natural systems. *Nature***421(6918)**: 37–42.

PERRY, A.L., LOW, P.J., ELLIS, J.R. AND REYNOLDS, J.D. 2005. Climate change and distribution shifts in marine fishes. *Science***308**: 1912–1915.

PARRY, M., ROSENZWEIG, C. and LIVERMORE, M. 2005. Climate change, global food supply and risk of hunger.*Philos. Trans. R. Soc. Lond. B. Biol. Sci.***360**: 2125-2138

PLANQUE, B., FROMENTIN, J.M., CURT, P., DRINKWATER, K.F., JENNINGS, S., PERRY, R.I. and KIFANI, S. 2010. How does fishing alter marine populations and ecosystems sensitivity to climate? *J. Mar. Res.***79(3-4)**: 403-417.

RAHAMAN, M.M., SAJIB, K.I. and ALAM, I. Undated. A STUDY ON CLIMATE CHANGE IMPACT ON THE LIVELIHOODS OF THE PEOPLE IN TANGUAR

HAOR , BANGLADESH.

RODRIGU, F. 2002. Changes in climate variability and seasonal rainfall extremes: a case study from San Fernando (Spain), 1821-2000. *Theor. and App. Climtol.***72**: 193–207.

SALLU, S.M., TWYMAN, C. and STRINGER, L.C. 2010 Resilient or vulnerable livelihoods? Assessing livelihood dynamics and trajectories in rural Botswana. *Ecol. Soc.***15(4)**: 3.

SCHMIDHUBER, J. and TUBIELLO, F. N. 2007. Global food security under climate change.*PANS* **104**: 19703-19708.

SCHOLZE, M., KNORR, W., ARNELL, N.W. and PRENTICE, I.C. 2006. A climate-change risk analysis for world ecosystems. *Proc. Natl. Acad. Sci. U. S. A.***103(35)**: 13116–20.

SHAHID, S. 2011. Trends in extreme rainfall events of Bangladesh. *Theor. Appl. Climatol.***104**: 489–499.

SHAHID, S. and BEHRAWAN, H. 2008. Drought riskk assessment in the western part of Bangladesh. *Nat. Hazards* **46**: 391-413.

SIN, S. 2000. Late Quaternary geology of the ower Central Plain, Thailand. *J. Asian Earth Sci.* **18**: 415-426.

SINISCALCO, M.T. and AURIAT, N. 2005. Questionnaire design. *In:* ROSS, K.N. (ed.). *Quantitative Research Methods in Educational Planning.* Paris: UNESCO International Institute for Education Planning.

SMIT, B. and WANDEL, J. 2006. Adaptation, adaptive capacity and vulnerability. *Glob. Environ. Change***16(3)**: 282–292.

SPERLING, F. 2003. *Poverty and Climate Change: Reducing the Vulnerability of the Poor.*World Bank, Washington, DC,US.

STENSETH, N.C., OTTERSEN, G., HURRELL, J.W., MYSTERUD, A., LIMA, M., CHAN,

K.S., YOCCOZ, N.G. and ADLANDSVIK, B. 2003. Studying climate effects on

ecology through the use of climate indices: the North Atlantic Oscillation, El Nino Southern Oscillation and beyond. *Proc. R. Soc. Lond. B. Biol. Sci.***270**: 2087–2096.

TOL, R.S.J. and YOHE, G.W. 2007. The weakest link hypothesis for adaptive capacity: An empirical test. *Glob. Environ. Change.***17(2)**: 218–227.

TUBIELLO, F.N., SOUSSANA, J.F. and HOWDEN, S.M. 2007. Crop and pasture response to climate change. *PNAS* **104**: 19686-19690.

TURNER, B.L., KASPERSON, R.E. MATSON, P.A. MCCARTHY, J.J. CORELL, R.W. CHRISTENSEN, L., ECKLEY, N., KASPERSON, J.X., LUERS, A., MARTELLO, MARYBETH L., POLSKY, C., PULSIPHER, A. and SCHILLER, A. 2003. A framework for vulnerability analysis in sustainability science. *Proc. Natl. Acad. Sci. U. S. A.***100(14)**: 8074–8079.

TUSAR, K.D. and MOUMITA, C. 2013. Climate change influence water use pattern in south-west coastal belt of Bangladesh. *J. Environ. Sci.and Natural Resouces***6(2)**: 217–225.

ULLAH, M.B. and RAHMAN, M.H. 2014. Assessing Vulnerability and Adaptation to Climate Change by Farming Communities in Southwestern Coastal Bangladesh. *J. Environ. Sci. & Natural Resources* **7(2)**: 31–35.

UNFCCC Undated. United Nations Framework Convention on Climate Change.

VINCENT, K. 2007. Uncertainty in adaptive capacity and the importance of scale. *Glob. Environ. Change***17(1)**: 12–24.

WATTS, M.J. and BHOLE, H.G. 1993. The space of Vulnerability: the causal structure of hunger and famine. 43–67.

WISNER, B., BLAIKIE, P., CANNON, T. and DAVIS, I. 2004. *At risk: natural hazards, people's vulnerability, and disasters*. 2nd (ed.). Routledge, London.

WMO. 2008. World Meteorological Organization. Statement on Status of the Global Climate in 2007. WMO-No. 10.

WORLD BANK. 2000. Seas, and Storms:Managing Change in Pacific Island Economies

Volume **IV**: Adapting to Climate Change, Washington, District of Columbia.

WORLD BANK. 2010. Zila level povmap estimates. 2010.

WORLD BANK. 2013. World Deelopment Indicators: Bangladesh (Online). The World Bank. Available: http://data.worldbank.org/country/bangladesh#cp_wdi

WORLD BANK 2014. The World Bank. Available: http://data.worldbank.org/country/bangladesh.

Yu, W.H., ALAM M., HASSAN, H., KHAN, A.S., RUANE, A.C., ROSENZWEIG, C., MAJOR, D.C. AND THURLOW,J. 2011. *Climate Change Risks and Food Security in Bangladesh*. Earthscan London. Washington, DC.

Appendices

Appendics 1: Description of the terms.

Bangladesh context: Bangladesh is situated in latitudes 20°34′N to 26°38′ N and longitudes 88°01′ E to 92°41′ E. It shares borders with India in north, east and west. The south-east side is bordered with Myanmar and the Bay of Bengal is situated in the south side of Bangladesh. The area of the country is 147570 sq. km. According to World Bank 2014 report, the population of the country is 159.1 million. Bangladesh has a sub-tropical monsoon climate with six seasons. Mean annual temperature is approximately 26°C over most of the country (Met Office 2011). The maximum temperature recorded in summer is 37°C (98°F) although in some places this occasionally rises up to 41°C (105°F) or more. In winter the fluctuation of temperatures usually ranges from minimum 7°C-13°C (45°F-55°F) to maximum of 24°C-31°C (75°F-85°F). The average annual rainfall varies from 1429-4338 mm. In coastal areas of Chittagong and northern part of Sylhet district maximum rainfall is recorded whereas the minimum is observed in the western and northern parts of the country.

Climate change Impacts: The effects of climate change on natural and human systems.

Climate projection:The calculated response of the climate system to emissions or concentration scenarios of greenhouse gases and aerosols, or radiative forcing scenarios, often based on simulations by climate models. Climate projections are distinguished from climate predictions, in that the former critically depend on the emissions/concentration/radiative forcing scenario used, and therefore on highly uncertain assumptions of future socio-economic and technological development.

Climate variability: Climate variability refers to variations in the mean state and other statistics (such as standard deviations, statistics of extremes, etc.) of the climate on all temporal and spatial scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural oranthropogenic external forcing (external variability) (IPCC 2007a).

Culture Fisheries/ Aquaculture: Fisheries is an important branch of biological science which deals with management, development, culture, technology and livelihood related to fish and fish related to aquatic and semi-aquatic organisms of economic importance.

Fisheries: Fisheries is an important branch of biological science which deals with management, development, culture, technology and livelihood related to fish and fish related to aquatic and semi-aquatic organisms of economic importance.

Divisions and Districts of Bangladesh: Bangladesh is divided into eight administrative regions which is called division. They are Dhaka, Chittagong, Mymensingh, Sylhet, Rangpur, Rajshahi, Khulna and Barisal. Each division is further subdivided into several districts. Dhaka division have 13 districts, Mymensingh have 4 districts, Chittagong have 11 districts, Rajshahi and Rangpur have 8, Barisal have 6 districts, Khulna have 10 districts and Sylhet have 4 districts.

Vulnerability mapping: Mapping the vulnerability is creating the spatial distribution of system vulnerability which is useful in helping policymakers to identify the most vulnerable subunits. A vulnerability map gives the precise location of sites where people, the natural environment or property are at risk due to a potentially catastrophic event that could result in death, injury, pollution or other destruction. Such maps are made in conjunction with information about different types of risks. Vulnerability maps are most often created with the assistance of computer technology called geographic information systems (GIS).

Appendix 2: District wise annual fish production from 2001 to 2014.

Districts	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14
Dhaka	16,712	14,254	28,775	45,478	47,299	44,876	45,023	45,879	40,803	37432	20177.54	16215.8	18569
Faridpur	20,452	11,665	15,619	15,310	15,128	15,236	14,150	17,667	18,277	18758	25244.39	25659	25746
Gazipur	18,376	28,337	27,180	35,790	23,463	28,726	47,217	45,277	34,771	38275	37470	38710	50428
Gopalgonj	13,158	9,908	10,756	10,905	12,716	14,044	16,614	14,148	32,498	36493	22354.94	23031	27159
Jamalpur	10,125	13,029	17,775	20,865	22,589	19,642	18,495	19,922	21,703	27154	19439.1	23039	26432
Kishorgonj	39,708	35,312	43,115	48,764	56,049	63,081	61,396	66,014	55,078	56818	58210.82	55176	63788
Madaripur	8,520	9,696	9,799	11,224	11,641	12,903	13,661	14,864	15,834	15831	15065.39	16366.7	17237
Manikgonj	13,096	11,010	11,921	13,574	13,511	17,728	17,077	18,085	10,368	19643	19151.25	20171.1	21206
Munshigonj	8,735	7,506	8,996	11,108	12,030	13,894	10,683	14,511	11,535	12220	23205.57	24208.2	25686
Mymensingh	75,540	56,523	65,171	72,263	74,011	85,377	82,886	72,129	220,108	260134	288588.1	302563	316951
Narayanganj	15,088	16,350	14,569	30,009	32,024	28,817	29,433	40,924	28,538	29704	15236.28	18631.8	15714
Narsingdi	12,019	13,566	12,367	15,358	14,980	18,006	16,120	18,885	18,621	19777	24289	26674	32490
Netrakona	23,885	33,906	36,034	46,950	50,094	59,406	59,421	69,365	59,978	70777	41788.15	52893.8	56725
Rajbari	8,791	11,995	14,085	13,839	14,931	15,205	19,085	18,536	16,457	17181	17636	20172.2	21315
Shariatpur	12,379	11,319	11,072	12,251	15,353	15,232	15,285	14,016	15,543	17614	16594.71	18049.6	20231
Sherpur	4,558	8,731	11,242	13,690	15,783	15,710	17,572	20,148	25,047	26163	21622	22566	25177
Tangail	14,572	17,434	19,511	22,048	20,585	21,286	25,941	21,045	34,371	34453	37065.69	41054.4	49163
Bagerhat	50,961	52,601	55,718	70,353	68,576	70,175	69,093	69,858	95,952	101830	102381.8	99779.5	92044
Chuadanga	4,982	6,302	6,164	7,090	7,675	7,457	8,192	8,621	11,428	11546	I1684.00	11181.2	11566

Jessore	30,348	36,625	37,202	39,844	37,907	41,361	41,836	50,810	86,694	86609	146384.5	154846	172117
Jhenaidah	12,978	18,320	19,675	17,014	19,293	19,503	18,289	19,139	19,552	21006	26060.48	27779.1	29969
Khulna	63,247	63,525	72,089	61,267	57,581	63,416	69,105	66,213	47,951	56920	57294.26	63502.1	77102
Kustia	11,344	9,746	10,596	11,636	14,243	14,294	16,632	21,180	25,444	28564	21213.11	20042	17809
Magura	10,581	12,120	12,303	12,576	10,737	12,861	12,437	11,126	11,278	13609	10186.22	11420	12570
Meherpur	3,557	4,641	4,956	5,363	4,495	5,333	4,760	5,178	6,752	7155	7821	6816	7634
Narail	6,624	7,921	10,401	9,941	4,495	10,938	12,069	12,699	9,093	11356	12117.51	11096	11371
Satkhira	29,255	34,449	38,895	37,754	45,197	43,780	48,352	44,705	49,871	59529	73964.44	102761	116343
Barguna	19,389	18,145	20,890	20,182	22,050	22,679	23,015	21,564	16,871	19107	12468.99	12491.8	10903
Barisal	49,675	47,780	48,350	50,209	69,021	65,182	68,075	60,456	68,740	54137	59111.91	67626.5	75741
Bhola	44,836	40,228	43,255	44,206	50,344	57,170	58,147	52,676	52,122	43535	57489	68116.7	85006
Jhalokati	15,608	10,568	10,794	10,656	10,313	9,078	9,747	9,593	7,852	8125	7779.96	8963.12	10082
Potuakhali	24,616	25,972	28,709	29,390	31,412	30,951	33,262	33,191	27,393	29024	44226.64	40765.3	35053
Pirojpur	20,050	17,200	19,073	17,480	19,108	22,135	19,294	19,372	25,884	26625	21343.98	18536.9	13560
Dinajpur	45,782	46,554	43,855	36,794	42,005	45,827	46,832	43,696	37,740	32833	35073.25	38036.2	38892
Gaibandha	12,694	13,342	13,749	13,487	16,028	15,014	29,390	29,773	29,727	29338	16362	17097.7	18197
Kurigram	15,473	15,350	16,336	13,291	15,503	15,359	15,500	15,372	17,272	16296	21578.57	23469	21265
Lalmonirhat	9,266	7,115	6,318	6,486	6,756	6,284	7,636	7,124	10,155	10276	9271.22	10357.7	10658
Nilphamari	11,101	6,778	6,897	6,374	6,559	7,450	7,755	8,636	11,150	10981	11524.12	12566.3	12746
Panchagarh	9,314	11,265	13,764	12,490	11,682	12,592	14,668	16,136	9,514	8427	8240.42	10541.9	9782
Rangpur	9,468	9,618	10,206	10,752	12,256	12,121	13,896	15,267	18,990	19456	18812.81	21598.2	22706
Thakurgaon	12,193	14,559	17,006	15,416	15,750	16,044	19,977	19,192	19,125	19451	20039.48	18584.2	19398
Bogra	25,596	25,822	31,438	28,735	39,502	38,336	33,878	40,326	56,629	60727	62592.47	64099	65454
Chapainawabganj	11,101	14,710	15,453	12,989	12,970	14,164	17,546	21,502	14,464	13797	13918.08	14644	17946
Joypurhat	13,827	11,052	12,264	9,120	12,181	13,398	16,178	17,613	22,123	23071	20947.12	21686.8	17458
Naogaon	30,928	60,450	59,754	39,668	32,091	37,172	40,366	63,590	74,447	77396	62884.32	64087.6	65889
Natore	21,582	28,890	25,215	29,017	24,146	25,841	27,421	30,932	31,231	31478	35931.33	36289	40496
Pabna	24,928	28,046	31,234	32,195	47,278	48,904	33,585	35,738	47,409	48780	45797.9	58129.2	65287

Rajshahi	34,555	37,001	33,484	42,172	30,352	33,921	41,496	43,884	74,824	74943	68209	65645.3	63984
Sirajganj	19,705	21,015	21,254	22,092	25,353	27,524	36,016	38,282	31,693	35243	45449.33	41478	55210
Bandarban	859	625	470	285	222	115	129	171	1761	1891	1347.38	1339.87	1608
Brahmanbaria	47,350	55,384	42,015	44,774	42,372	42,159	45,970	47,458	36,511	37049	46187	43475	43108
Chandpur	37,277	40,683	42,588	49,046	42,308	48,828	56,678	60,036	70,067	66925	81953.12	63057.3	78838
Chittagong	63,223	69,932	65,404	55,682	95,687	95,259	95,482	100,953	77,033	79095	88047.17	89988.9	57232
Comilla	58,926	68,946	70,585	77,379	88,334	79,887	78,314	94,215	113,315	115831	150673.2	154700	195997
Cox's Bazar	44,019	45,007	45,469	45,610	44,736	48,491	51,887	56,046	34,155	44372	40314.74	31715.2	30012
Feni	16,349	16,942	16,379	18,703	18,944	23,421	27,585	39,073	38,210	39222	35136	39492.6	30094
Khagrachhari			13	11	11	11	10	10	2,480	2524	3210	2695	2113
Lakshmipur	32,327	38,575	41,876	49,790	48,877	50,924	57,982	62,628	57,881	58620	51681	53975	60281
Noakhali	52,464	50,438	48,020	48,299	50,304	52,132	51,895	55,915	53,086	53743	101873.6	102486	89016
Rangamati	7,247	7,025	7,281	7,417	7,584	8,119	8,276	8,619	8,113	9624	10225.21	10936	10190
Habiganj	11,018	18,424	20,194	26,015	16,315	20,514	19,680	17,065	17,865	19435	43343	43779	48246
Moulvibazar	20,889	18,712	20,633	20,791	21,362	26,512	29,854	31,598	33,218	34156	42899.78	53232	32259
Sunamganj	21,178	43,787	42,138	49,184	53,318	61,980	74466	79,773	72,123	83192	62617.72	85074.4	85300
Sylhet	44,859	23,557	28,467	32,906	38,825	38,785	43,009	48,308	37,198	40078	52355	56105.7	50181

Appendix 3: Capture production from the year 2001-2014.

Districts	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-2010	2010-11	2011-12	2012-13	2013-14
Dhaka	11481	8718	23003	39461	41164	38810	37281	37984	35831	32331	11908	5593	5650
Faridpur	12426	4750	7317	6899	6895	6316	4134	6434	7482	7449	11009	11683	11146
Gazipur	12213	21950	20548	28361	15086	20699	39212	35746	20361	20282	16194	16603	17774
Gopalganj	8099	4577	5065	5448	7481	7577	8578	6134	10006	6275	8731	10918	7801
Jamalpur	7853	9788	13648	16680	17589	14333	12910	13451	13244	13220	7136	6825	9955
Kishoreganj	32530	26059	29793	34053	42419	47281	45120	48845	40468	41332	36165	33365	41111
Madaripur	3600	4771	4726	6648	6861	7649	7939	8983	9569	9080	7096	8107	9240
Manikganj	7741	5848	6096	6253	7252	10560	10269	11101	7113	12303	12163	10883	11567
Munshiganj	4582	3176	3905	5526	7387	8871	5217	9023	7994	8327	17610	17416	13511
Mymensingh	52721	33209	41150	45993	46845	56645	53960	42945	38782	40819	40174	26457	15037
Narayanganj	12484	13584	11243	26443	27846	24618	25241	35843	8352	24094	6742	9345	3156
Narsingdi	7514	8891	7211	9696	9233	12857	11021	12594	23473	8596	11603	11195	13275
Netrakona	9964	18224	17443	27694	31558	39272	38375	47931	40498	43496	15992	26201	30609
Rajbari	4370	7313	8637	8898	9990	9542	13203	12336	10319	10560	9846	9573	9162
Shariatpur	8553	6351	5773	6709	10472	9819	10136	7613	7254	7875	7583	7164	8442
Sherpur	2653	6245	8319	10009	12887	12188	13862	15632	14441	15165	5555	6245	6239
Tangail	9271	11829	12720	14648	13220	14780	19392	13204	9511	9777	7067	11302	13757
Bagerhat	10213	9094	9994	24158	21861	23474	21232	19287	28486	32613	27550	25992	25139
Chuadanga	2054	2639	2222	2545	2918	2822	3328	3519	3379	3392	3331	1693	2111
Jessore	8514	11205	11269	10613	11325	13960	13702	21023	19513	19176	28213	27020	36900
Jhenaidah	3551	6474	5008	6174	5266	4998	2569	1898	2065	2107	6092	7453	7473
Khulna	21977	22828	25141	13472	16544	17186	17421	14130	8235	8973	9041	8466	21209
Kushtia	7114	5693	5962	7767	9557	10022	11327	15686	14298	14448	7202	4586	4803

Magura	5047	5553	4231	4459	3377	4161	3577	2313	1902	2208	3883	3746	3650
Meherpur	1775	2553	2207	2389	1997	2710	2071	2207	2221	2342	2969	1843	1939
Narail	2535	2265	1934	2124	1736	2001	3072	3868	3741	3778	3136	3631	4245
Satkhira	3967	5070	5890	5650	8451	8868	11777	7070	3770	4199	4808	4385	13343
Barguna	10681	9550	10791	10092	10350	10229	9953	35899	9672	13751	4875	5775	5097
Barisal	33897	32300	31148	33297	45764	42628	44175	9415	37226	28521	22397	30060	31845
Bhola	29338	24414	23543	23670	23973	31099	31167	25127	28181	27308	30456	35479	51001
Jhalokati	8308	3372	3261	3056	3291	2570	2342	2280	3420	4334	4662	4677	5861
Patuakhali	8256	9580	10524	11259	10807	9158	10553	10405	13460	15755	13996	14622	13482
Pirojpur	11421	9183	8525	6772	7427	6873	5933	5526	5781	9667	6867	6517	4416
Dinajpur	13389	12907	12168	10411	13683	13959	14178	10037	9856	9690	32270	6455	6858
Gaibandha	9635	10114	9378	10008	11994	10633	23735	23793	22670	22906	16094	6076	6171
Kurigram	10700	10849	11151	9176	10793	10531	10412	9664	8754	8813	20978	11777	8226
Lalmonirhat	7150	4499	3380	4396	4407	3817	3986	3593	3413	3331	8954	2640	2163
Nilphamari	4946	4963	4149	4187	3966	4624	3931	4386	4370	4091	11431	4348	3831
Panchagarh	1387	2383	2180	2771	3264	3134	4489	3764	3506	3582	8240	2197	2031
Rangpur	5537	5855	5230	6022	8269	7982	8650	8946	9888	10471	17996	7508	7425
Thakurgaon	1205	2387	2214	2361	4152	3996	3885	4279	4164	4140	19885	2318	2986
Bogra	11201	8639	9465	8838	15276	14272	8070	13356	13350	12772	61485	17656	7359
C. Nawabganj	3512	6523	5630	5366	5480	5296	5096	6988	6858	5996	13797	7203	6057
Joypurhat	5030	3858	3831	3790	5340	6057	7061	7141	7885	8165	20366	5541	809
Naogaon	10491	36984	36084	31107	12761	13463	16297	36910	33233	31641	60075	16918	18043
Natore	4322	10784	10860	13548	11207	13089	13850	15076	13936	13887	35502	10683	14578
Pabna	11583	14783	15683	15439	29247	30216	14368	15555	13766	12892	43621	16511	13922
Rajshahi	13607	9315	10446	10418	10493	12274	15920	15838	16377	14844	63160	17547	10584
Sirajganj	6602	8240	8020	8346	15960	17306	19751	20389	19868	20162	41041	22575	39360
Bandarban	859	625	470	285	222	115	129	171	162	273	1342	188	173
Brahmanbaria	13126	14826	13074	15915	17017	17463	19046	19243	17581	17746	45252	17192	17010
Chandpur	19163	20130	21173	27332	24772	27381	33466	35527	38962	35281	80360	29169	41746
Chittagong	14913	14014	11354	15083	38330	36164	39953	44435	41637	42247	86145	42937	4086
Comilla	20913	23412	22008	30914	43008	35662	33966	48381	44883	44917	118704	14501	64972

Cox's Bazar	6245	6669	5128	5692	7290	5707	5961	6010	5757	7153	6422	7282	3994
Feni	5011	5258	4321	6311	8350	11235	15504	26377	24283	25232	30046	19364	8130
Khagrachhari	0	0	13	11	11	11	10	10	126	84	2180	114	140
Lakshmipur	22688	24818	25312	101417	30680	32036	37933	41605	37581	38350	51427	16305	30091
Noakhali	15945	14042	11843	14145	17537	18043	17568	20068	20951	20942	93513	53229	41484
Rangamati	7247	7025	7281	7417	7584	8119	8276	8619	7586	9082	9330	9182	8318
Habiganj	3503	10165	11549	17558	8986	12720	11253	7978	7836	9197	42466	31107	35834
Maulvibazar	13086	10794	11385	11690	13254	17853	20025	20459	18562	19360	41867	40776	19029
Sunamganj	11987	33817	31622	38688	45173	51443	62647	66196	52609	62261	61981	77524	77363
Sylhet	36731	13599	17418	22229	29351	27584	30716	33679	29479	31524	50200	29815	33086

Appendix 4: Culture Production by district from the year 2001-2014.

Districts	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14
Dhaka													
Faridpur	5926.13	5536	5772	6017.3	6135	6066.36	7742	7895	269	5101	8270	10623	12919
Gazipur	7331	6915	8302	15551	8233	8920.24	10016	11233	277	11309	14235	13976	14600
Gopalganj	6194.03	6387	6632	7429	8377	8027	8005	9531	806	17993	4598	22107	32654
Jamalpur	5028	5331	5691	5457.2	5235	6467.43	8036	8014	2066	30218	13624	12113	19353
Kishoreganj	2282.7	3241	4127	4185.3	5000	5309.28	5585	6471	136	13934	12303	16214	16477
Madaripur	7178.41	9253	13322	14711	13630	15800.4	16276	17169	65	15486	22046	21811	22677
Manikganj	4909	4925	5073	4576.5	4780	5254.3	5722	5881	775	6751	7969	8260	7997
Munshiganj	5355	5162	5825	7321	6259	7168	6808	6984	156	7341	6988	9288	9639
Mymensingh	4153	4330	5091	5539	4643	5023	5466	5488	184	3893	5596	6792	12175
Narayanganj	22819	23314	24021	26270	27166	28732	28926	29184	345	219315	248414	276106	301914
Narsingdi	2604	2766	3326	3566	4178	4199	4192	5081	537	5610	8494	9287	12558
Netrakona	4505	4675	5156	5662	5747	5149	5099	6291	184	11181	12685	15479	19215
Rajbari	13921	15682	18591	19256	18536	20134	21046	21434	231	27281	25796	26693	26116
Shariatpur	4421.27	4682	5448	4941.5	4941	5663.49	5882	6200	255	6621	7790	10599	12153
Sherpur	3826	4968	5299	5542.4	4881	5413.41	5149	6403	484	9739	9012	10886	11789
Tangail	1905	2486	2923	3681	2896	3522	3710	4516	83	10998	16067	16321	18938
Bagerhat	40511.3	5605	6791	7400	7365	6506	6549	7841	353	24676	29999	29752	35406
Chuadanga	5538	43507	45724	46195	46715	46701.1	47861	50571	50423	69217	74832	73788	66905
Jessore	3311.12	3663	3942	4545	4757	4635	4864	5102	1498	8154	8353	9488	9455
Jhenaidah	21453.4	25420	25933	29231	26582	27401.4	28134	29787	17345	67433	118171	127826	135217
Khulna	30317.9	11846	14667	10840	14027	14505.3	15720	17241	3121	18899	19968	20326	22496
Kushtia	20377	40697	46948	47795	41037	46229.6	51684	52083	33646	47947	48253	55036	55893
Magura	4231.53	4053	4634	3869	4686	4272	5305	5494	393	14116	14011	15456	13006
Meherpur	5532	6567	8072	8117.5	7360	8699.72	8860	8813	704	11401	6303	7674	8920
Narail	1895.16	2088	2749	2974	2498	2623	2689	2971	611	4813	4852	4973	5695

Satkhira	23563.8	5656	8467	7816.7	7247	8937.49	8997	8831	2252	7578	8982	7465	7126
Barguna	5815.49	29379	33005	32104	36746	34911.6	36575	37635	36901	55330	69156	98376	103000
Barisal	8591.54	8595	10099	10090	11700	12450.4	13062	24557	242	5356	7594	6717	5806
Bhola	15780.8	15480	17202	16912	23257	22553.8	23900	12149	3728	25616	36715	37567	43896
Jhalokati	15478	15814	19712	20536	26371	26071.3	26980	27549	2671	16227	27032	32638	34005
Patuakhali	7346.24	7196	7533	7599.9	7022	6508.11	7405	7313	926	3791	3118	4286	4221
Pirojpur	17169.5	16392	18185	18131	20605	21793	22709	22786	1886	13269	30231	26143	21571
Dinajpur	7774	8017	10548	10708	11681	15261.6	13361	13846	3900	16958	14477	12020	9144
Gaibandha	32393	33647	31687	26383	28322	31868	32654	33659	415	23143	37877	31581	32034
Kurigram	3059	3228	4371	3479	4034	4381	5655	5980	129	6432	16630	11022	18197
Lalmonirhat	4773	4501	5185	4115	4710	4828	5088	5708	230	7483	22179	11692	1817
Nilphamari	2116	2616	2938	2090	2349	2467	3650	3531	161	6945	9588	7718	8495
Panchagarh	1929	1815	2748	1748	2593	2826	3824	4250	52	6890	11617	8218	8915
Rangpur	7927	8882	11584	9719	8418	9458	10179	12372	5	4845	8241	8345	7751
Thakurgaon	3931	3763	4976	4730	3987	4139	5246	6321	529	8985	19630	14090	15281
Bogra	10988	12172	14792	13055	11598	12048	16092	14913	11	15311	20194	16266	16412
C. Nawabganj	14395	17183	21973	19897	24226	24064	25808	26970	133	47955	63700	46443	58095
Joypurhat	7589	8187	9823	7623	7490	8868	12450	14514	20	7801	14039	7441	11889
Naogaon	8797	7194	8433	5330	6841	7341	9117	10472	0	14906	21528	16146	16649
Natore	20437	23466	23670	8561	19330	23709	24069	26680	1908	45755	65694	47170	47846
Pabna	17260	18106	14355	15469	12939	12752	13571	15856	0	17591	36361	25606	25918
Rajshahi	13345	13263	15551	16756	18031	18688	19217	20183	2316	35888	47975	41618	51365
Sirajganj	20948	27686	23038	31754	19859	21647	25576	28046	1035	60099	73258	48098	53400
Bandarban	13103	12775	13234	13746	0	10218	16265	17893	72	15081	49858	18903	15850
Brahmanbaria	0	0	0	0	0	0	0	0	209	1618	1353	1152	1435
Chandpur	34224.1	40558	28941	28859	25355	24696	26924	28215	396	19303	47122	26283	26098
Chittagong	18568.4	20553	21415	21714	17536	21447.1	23212	24509	580	31644	83546	33888	36776
Comilla	47856	55918	54050	40599	57357	59095.5	55529	56518	1804	36848	89949	47052	53146
Cox's Bazar	57815.5	45534	48577	46465	45326	44225	44348	45834	7370	70914	182642	140199	131025
Feni	17972.3	38338	40341	39918	37446	42784.3	45926	50036	22931	37219	74207	24433	26018
Khagrachhari	11337	11684	12058	12392	10594	12185.6	12081	12696	685	13990	40226	20129	21964

Lakshmipur	1.45	0	0	0	0	0	0	0	339	2440	4240	2581	1973
Noakhali	9667	13757	16564	17373	18197	18887.7	20049	21023	409	20270	51935	37670	30190
Rangamati	36490	36396	36177	34154	32767	34088.9	34327	35847	1422	32801	110234	49257	47532
Habiganj	0	0	0	0	0	0	0	0	86	542	11102	1754	1872
Maulvibazar	7515	8259	8645	8457	7329	7794	8427	9087	23	10238	43343	12672	12412
Sunamganj	7803	7918	9248	9101	8108	8659	9829	11139	45	14796	43933	12456	13230
Sylhet	9191	9970	10516	10496	8145	10537	11819	13577	471	20931	63254	7550	7937
	8128	9958	11049	10677	9474	11201	12293	14629	251	8554	54510	26291	17095

Appendix 5: Area used for culture from the year 2003 to 2013.

Districts	2002	2003	2005	2007	2008	2009	2010	2011	2012	2013
Dhaka	2464	2555	2555	2555	2910	2075	6	2171	3902	6615
Faridpur	3938	4074	4074	4074	3719	3396	362	2351	5682	12701
Gazipur	3130	3249	3249	3249	3549	5250	325	3491	6657	9955.6
Gopalgonj	2834	2933	2933	2933	2823	8453	1482	3187	5138	9654.66
Jamalpur	1713	1789	1789	1789	1789	2268	25	8801	4998	4311
Kishorgonj	4727	5031	5031	5031	5231	4926	0	5305	7272	7551
Madaripur	2243	2322	2322	2322	2122	2528	282	602	2957	10587
Manikgonj	2422	2516	2516	2516	2516	1034	1	882	5112	4253.97
Munsigonj	1781	1852	1852	1852	1852	1551	188	872	3342	8124
Mymensingh	7835	8353	8353	8353	8353	27138	45	9544	28704	27723
Narayangonj	1328	1383	1383	1383	1383	3748	0	1892	5877	5994.13
Narsingdi	2027	2108	2108	2108	2108	1895	0	2047	3581	20369
Netrokona	6143	6550	6550	6550	6550	7145	4	2785	8179	9157.16
Rajbari	2252	2328	2328	2328	2138	2451	0	1585	4753	5022
Shariatpur	2000	2080	2080	2080	2080	3119	0	1149	3725	6637.39
Sherpur	1233	1291	1291	1291	1291	4237	38	2798	5007	4423
Tangail	2889	3017	3017	3017	3017	6892	17	4823	10411	11109
Bagerhat	50433	62324	62327	62327	62327	70038	66494	76234	81580	80341.2
Chuadanga	1888	1956	1956	1956	2397	2623	1112	1356	3540	3125
Jessore	8377	10852	14469	14469	13342	28422	16509	33239	35635	31806
Jhinaedah	5499	5824	5824	5824	5242	5535	898	4684	6039	8004.6
Khulna	35155	57878	57878	57878	58025	47526	50743	54202	59730	60642
Kushtia	1915	2000	2000	2000	2138	3049	372	2056	5713	4592.5
Magura	3050	3260	3260	3260	3150	3557	714	1198	2708	2872.61
Meherpur	1225	1274	1274	1274	1164	1753	400	1415	1918	1848

Narail	2938	4069	4069	4069	3779	2231	2567	2267	5102	4240
Satkhira	32634	51606	55643	55643	55537	64939	68118	6274	93388	97923.4
Barguna	5079	5324	5115	5115	5115	198	699	2717	4189	3247.42
Barisal	7415	7819	7930	7930	7930	946	758	6273	16810	37836.2
Bhola	8519	10255	12109	12109	12795	688	55	5277	8560	8750.29
Jhalokathi	2464	2598	2568	2568	3375	3	142	722	1857	2246.34
Patuakhali	8371	11667	11684	11684	11684	1655	4863	9537	19644	15971.3
Pirojpur	6585	8519	9013	9013	9119	3143	2115	1196	5943	25197
Dinajpur	10152	10662	10662	10662	10662	30504	313	8128	9157	11061.1
Gaibandha	1777	1844	1844	1844	1844	277	0	1830	3271	4374.04
Kurigram	1894	1966	1966	1966	1966	1	3	2784	4075	5475.51
Lalmonirhat	1080	1124	1124	1124	1124	2	151	2928	2495	6045.48
Nilphamari	1362	1414	1414	1414	1414	150	0	1898	3012	3107.52
Panchagarh	3781	3970	3970	3970	3970	4	0	1816	2289	2525
Rangpur	1857	1925	1925	1925	1925	0	1	4759	4077	5882.4
Thakurgaon	5016	5259	5259	5259	5259	5	8	4653	5251	5157.84
Bogra	9012	9477	9477	9477	9477	774	29	9447	11455	18606
C.Nawabganj	4912	5081	5081	5081	5081	28	0	1974	2100	7341
Joypurhat	2913	3062	3062	3062	3062	0	0	3218	4260	4281.52
Naogaon	10398	10768	10768	10768	10768	5	12	10730	12034	12233.9
Natore	5702	5909	5909	5909	5909	0	2	4923	7023	7040.5
Pabna	7070	7324	7324	7324	7324	8	1	8725	10282	18312.1
Rajshahi	7461	7729	7729	7729	7729	0	0	11076	10124	19848
Sirajganj	6701	6917	6917	6917	6917	0	2	7214	5242	5408
Bandarban	0	0	0	0	0	1504	0	284	619	566
B.Baria	7856	8326	8326	8326	8326	97	0	6333	6831	8400
Chandpur	7026	7448	7448	7448	7448	46	48	8768	10214	19759.6
Chittagong	20076	21000	22803	22803	22803	32	2427	12714	20014	21221.5
Comilla	13088	13875	13875	13875	13875	57795	0	30764	24509	38475.2
Cox’s Bazar	37081	37469	40578	40578	40578	2127	62907	16534	46887	48574.6
Feni	4185	4436	4436	4436	4436	464	124	6079	5044	7293.35

Khagrachari	0	0	0	0	0	124	26	2514	1222	1027
Lakshmipur	6174	6547	6547	6547	6547	60	0	4017	11011	10753.1
Noakhali	11712	12387	12387	12387	12387	201	385	12683	14625	18617.3
Rangamati	0	0	0	0	0	249	56	906	742	1241
Habiganj	3343	3441	3441	3441	3441	4386	1	2119	3860	3992
Moulov.Bazar	4118	4234	4234	4234	4234	5024	80	3118	4613	4773.5
Sunamgonj	4456	4573	4573	4573	4573	17003	0	2342	2470	5256
Sylhet	4629	4761	4761	4761	4761	4662	90	4453	6541	6612.81

Appendix 6: District wise total water area used in fisheries.

Districts	Water area in square meter
Dhaka	12124295.28
Faridpur	11860510.55
Gazipur	10114242.01
Gopalganj	16009376.06
Jamalpur	13612810.79
Kishoreganj	56632072.16
Madaripur	5484009.00
Manikganj	6936817.16
Munshiganj	233325.26
Mymensingh	40974657.21
Narayanganj	2300999.90
Narsingdi	6626642.77
Netrakona	73014629.71
Rajbari	9343939.18
Shariatpur	1684749.94
Sherpur	14277532.64
Tangail	21158455.05
Bagerhat	960245.09
Chuadanga	18166621.26
Jessore	58876266.75
Jhenaidah	37991503.89
Khulna	12450362.53
Kushtia	8420550.34
Magura	6087183.99
Meherpur	9276245.53
Narail	10183554.13
Satkhira	12624357.27
Barguna	
Barisal	17014362.51
Bhola	
Jhalokati	94438.36
Patuakhali	1966733.94
Pirojpur	
Dinajpur	14257526.96
Gaibandha	10371761.34

Kurigram	16491133.98
Lalmonirhat	4781108.11
Nilphamari	13130465.00
Panchagarh	2282704.06
Rangpur	20984217.45
Thakurgaon	15258799.71
Bogra	12087255.12
Chapai Nawabganj	21970608.02
Joypurhat	751356.00
Naogaon	44850761.36
Natore	11520750.19
Pabna	18041165.37
Rajshahi	50819279.57
Sirajganj	6822011.74
Bandarban	106391.92
Brahmanbaria	10147753.37
Chandpur	3554079.33
Chittagong	2508415.02
Comilla	3261785.93
Cox's Bazar	8425128.57
Feni	297650.06
Khagrachhari	5115565.21
Lakshmipur	1090293.17
Noakhali	1897592.77
Rangamati	550287301.39
Habiganj	30828811.23
Maulvibazar	85422649.09
Sunamganj	273722116.85
Sylhet	73304549.04

Appendix 7: By district poverty, GDP and expenditure value.

Districts	% poor (upper)	GDP	Expenditure
Dhaka	15.7	66548	3585.02
Faridpur	36.3	30405	2187.76
Gazipur	19.4	45481	3145.79
Gopalganj	42.7	31984	2171.74
Jamalpur	51.1	32922	1674.71
Kishoreganj	30.3	29325	2284.4
Madaripur	34.9	33895	2216.29
Manikganj	18.5	35347	2370.66
Munshiganj	28.7	29713	2387.93
Mymensingh	50.5	32629	2214.93
Narayanganj	26.1	47707	2645.79
Narsingdi	23.7	37021	2638.98
Netrakona	35.3	31780	2082.75
Rajbari	41.9	32615	1933.93
Shariatpur	52.6	30277	2077.26
Sherpur	48.4	34354	1769.93
Tangail	29.7	30957	2540.79
Bagerhat	42.8	48696	1949.27
Chuadanga	27.7	33955	2157.52
Jessore	39	39242	1923.67
Jhenaidah	24.7	34131	2869.78
Khulna	38.8	58346	2087.19
Kushtia	3.6	35036	3643.75
Magura	45.4	35171	2274.4
Meherpur	15.2	36414	2859.55
Narail	20	37911	2349.04
Satkhira	46.3	37083	2014.21
Barguna	19	40225	2856.29
Barisal	54.8	37934	1993.92
Bhola	33.2	37023	2329.24
Jhalokati	40.5	30407	2355.32
Patuakhali	25.8	38582	2468.02
Pirojpur	44.1	33453	2048.38
Dinajpur	37.9	34811	2319.51
Gaibandha	48	29090	1853.59
Kurigram	63.7	35107	1630.71
Lalmonirhat	34.5	32528	1727.96

Nilphamari	34.8	27870	2023.12
Panchagarh	26.7	30477	2319.51
Rangpur	46.2	32232	2420.71
Thakurgaon	27	36460	2524.92
Bogra	16.6	34396	2284.36
Chapai Nawabganj	25.3	28442	2336.83
Joypurhat	26.7	39664	2381.31
Naogaon	16.9	36223	2475.49
Natore	35.1	37940	1917.61
Pabna	31.5	38938	2161.37
Rajshahi	31.4	40008	2215.67
Sirajganj	38.7	29088	2005.79
Bandarban	40.1	29220	2456.61
Brahmanbaria	30	28318	2487.6
Chandpur	51	31998	1970.1
Chittagong	11.5	55281	3681.25
Comilla	37.9	24705	2355.17
Cox's Bazar	32.7	35225	2355.96
Feni	25.9	26225	3522.26
Khagrachhari	25.5	24556	2462.38
Lakshmipur	31.2	30862	2709.56
Noakhali	9.6	29565	3946.56
Rangamati	20.3	36934	2748.75
Habiganj	25.3	27915	2108.12
Maulvibazar	25.7	28797	2297.9
Sunamganj	26	25872	1978.95
Sylhet	24.1	31966	2943.12

Appendix 8: District wise electricity coverage, literacy rate, primary school and secondary school value.

Districts	Electricity coverage	Literacy rate	Primary School	Secondary School
Dhaka	97	70.54	1464	666
Faridpur	48.7	48.96	1512	248
Gazipur	84	62.6	1388	341
Gopalganj	49.1	58.09	1135	194
Jamalpur	39.4	38.44	2798	349
Kishoreganj	49.6	40.87	1498	250
Madaripur	59.3	47.97	297	159
Manikganj	52.7	49.2	612	156
Munshiganj	90.1	56.09	558	127
Mymensingh	41.3	43.49	1798	614
Narayanganj	95.3	57.1	519	195
Narsingdi	72.8	49.6	679	227
Netrakona	30.2	39.44	1166	259
Rajbari	45.8	52.28	655	147
Shariatpur	43.2	47.26	772	114
Sherpur	41.2	37.91	617	185
Tangail	56.2	46.79	1561	499
Bagerhat	40.8	58.98	1343	323
Chuadanga	60.6	45.91	747	137
Jessore	61.1	56.52	2351	531
Jhenaidah	58.6	45.91	987	298
Khulna	64.1	60.14	1982	411
Kushtia	64.1	46.33	1600	299
Magura	40.8	50.64	395	173
Meherpur	61.2	46.27	515	128
Narail	45.7	61.27	547	130
Satkhira	41.8	52.07	1311	324
Barguna	28.8	57.64	1317	176
Barisal	53.5	61.24	3060	435
Bhola	25.9	43.24	1743	266
Jhalokati	49	66.68	861	193
Patuakhali	31.8	54.07	1594	291
Pirojpur	42.9	64.85	1224	276
Dinajpur	39.4	52.42	664	674
Gaibandha	29.4	42.81	2289	398
Kurigram	20.8	42.52	948	355
Lalmonirhat	20.1	46.09	864	205

Nilphamari	34.5	44.37	876	296
Panchagarh	27	51.77	8	282
Rangpur	38.1	48.55	784	507
Thakurgaon	34.7	48.71	468	399
Bogra	52.6	49.38	338	467
Chapai Nawabganj	48.6	42.94	652	251
Joypurhat	51.6	57.48	601	160
Naogaon	39.4	48.22	1353	464
Natore	48.8	49.59	445	314
Pabna	60.1	46.72	1052	314
Rajshahi	62.1	52.98	911	571
Sirajganj	47.1	52.98	1583	390
Bandarban	28.2	35.86	341	52
Brahmanbaria	71.3	45.29	1040	234
Chandpur	55.6	56.78	1324	282
Chittagong	79.1	58.91	3106	730
Comilla	74.9	53.32	3976	617
Cox's Bazar	32.1	39.29	925	180
Feni	73.4	59.63	714	199
Khagrachhari	32.7	46.11	1186	95
Lakshmipur	43.8	49.4	702	172
Noakhali	51.1	51.29	1888	312
Rangamati	41.8	49.73	743	128
Habiganj	47.7	40.53	1281	145
Maulvibazar	50.8	51.1	1078	190
Sunamganj	34	34.98	1395	201
Sylhet	62.9	51.18	1352	335

Appendix 9: District wise housing structure, length of paved road and number of tube well.

Districts	Housing structure	Length of Paved Road	Tube well
Dhaka	45.6	289	761
Faridpur	4.8	232	393
Gazipur	11.6	366	431
Gopalganj	4	247	257
Jamalpur	2	259	600
Kishoreganj	2.8	363	675
Madaripur	4.7	144	276
Manikganj	3	195	351
Munshiganj	7.9	307	241
Mymensingh	3.6	462	1232
Narayanganj	20.7	226	625
Narsingdi	7.2	348	395
Netrakona	1.5	257	562
Rajbari	3.3	137	221
Shariatpur	2.8	132	261
Sherpur	7.4	213	385
Tangail	2.8	362	867
Bagerhat	5.1	298	218
Chuadanga	22.1	85	270
Jessore	16.4	317	653
Jhenaidah	14.9	386	428
Khulna	18.3	338	519
Kushtia	7.8	212	495
Magura	5.4	241	199
Meherpur	20	133	199
Narail	6.4	145	176
Satkhira	14.3	193	437
Barguna	2	160	203
Barisal	7.3	244	568
Bhola	1.7	213	381
Jhalokati	6.7	197	185
Patuakhali	2.6	255	354
Pirojpur	4	196	234
Dinajpur	5.5	378	753
Gaibandha	2	261	604
Kurigram	0.9	259	505
Lalmonirhat	1.6	172	361

Nilphamari	2.5	172	439
Panchagarh	10.6	158	229
Rangpur	3.6	333	788
Thakurgaon	2.8	165	343
Bogra	5.7	566	888
Chapai Nawabganj	13.1	213	376
Joypurhat	6	185	274
Naogaon	5.3	452	675
Natore	5.2	288	471
Pabna	7.1	437	620
Rajshahi	12.8	438	621
Sirajganj	2.3		701
Bandarban	3.6	271	50
Brahmanbaria	8.2	269	522
Chandpur	7.3	285	542
Chittagong	25	408	1279
Comilla	9.9	617	1007
Cox's Bazar	6.2	363	366
Feni	16.6	286	297
Khagrachhari	2.2	312	162
Lakshmipur	7.6	284	406
Noakhali	7.6	322	583
Rangamati	4.8	179	108
Habiganj	5.4	260	375
Maulvibazar	12.1	260	354
Sunamganj	6.6	213	488
Sylhet	21.7	463	446

Appendix 10: Future temperature, future precipitation, sea level rise, erosion, storm surge and cyclone data.

Districts	Future temperature	Future precipitation	Sea level rise	Erosion	Storm surge	Cyclone
Dhaka	3.75	7.5	0	0	0	0
Faridpur	3.75	7.5	0	0	0	0
Gazipur	3.75	7.5	0	0	0	0
Gopalganj	3.75	7.5	0	0	0	0
Jamalpur	3.75	7.5	0	0	0	0
Kishoreganj	3.75	7.5	0	0	0	0
Madaripur	3.75	7.5	0	0	0	0
Manikganj	3.75	7.5	0	0	0	0
Munshiganj	3.75	7.5	0	0	0	0
Mymensingh	3.75	7.5	0	0	0	0
Narayanganj	3.75	7.5	0	0	0	0
Narsingdi	3.75	7.5	0	0	0	0
Netrakona	3.75	7.5	0	0	0	0
Rajbari	3.75	7.5	0	0	0	0
Shariatpur	3.75	7.5	0	0	1	1
Sherpur	3.75	7.5	0	0	0	0
Tangail	3.75	7.5	0	0	0	0
Bagerhat	2.75	7.5	0	0	1	1
Chuadanga	3.75	7.5	0	0	0	0
Jessore	3.75	7.5	0	0	0	0
Jhenaidah	3.75	7.5	0	0	0	0
Khulna	2.75	7.5	5.6	5.6	1	1
Kushtia	3.75	7.5	0	0	0	0
Magura	3.75	7.5	0	0	0	0
Meherpur	3.75	7.5	0	0	0	0
Narail	3.75	7.5	0	0	0	0
Satkhira	2.75	7.5	0	0	1	1
Barguna	2.75	7.5	0	0	1	1
Barisal	3.25	7.5	0	0	1	1
Bhola	2.75	7.5	4.3	4.3	1	1
Jhalokati	2.75	7.5	0	0	1	1
Patuakhali	2.75	7.5	2.5	2.5	1	1
Pirojpur	2.75	7.5	0	0	1	1
Dinajpur	3.75	15	0	0	0	0
Gaibandha	3.75	15	0	0	0	0
Kurigram	3.75	15	0	0	0	0
Lalmonirhat	3.75	15	0	0	0	0

Nilphamari	3.75	15	0	0	0	0
Panchagarh	3.75	15	0	0	0	0
Rangpur	3.75	15	0	0	0	0
Thakurgaon	3.75	15	0	0	0	0
Bogra	3.75	7.5	0	0	0	0
Chapai Nawabganj	3.75	7.5	0	0	0	0
Joypurhat	3.75	7.5	0	0	0	0
Naogaon	3.75	7.5	0	0	0	0
Natore	3.75	7.5	0	0	0	0
Pabna	3.75	7.5	0	0	0	0
Rajshahi	3.75	7.5	0	0	0	0
Sirajganj	3.75	7.5	0	0	0	0
Bandarban	2.75	7.5	0	0	0	0
Brahmanbaria	3.75	7.5	0	0	0	0
Chandpur	3.75	7.5	0	0	1	1
Chittagong	2.75	7.5	2.55	2.55	1	1
Comilla	3.75	7.5	0	0	0	0
Cox's Bazar	2.75	7.5	1.75	1.75	1	1
Feni	3.75	7.5	0	0	1	1
Khagrachhari	2.75	15	0	0	0	0
Lakshmipur	3.25	7.5	2.3	2.3	1	1
Noakhali	3.25	7.5	3.9	3.9	1	1
Rangamati	2.75	11.25	0	0	0	0
Habiganj	3.75	7.5	0	0	0	0
Maulvibazar	2.75	15	0	0	0	0
Sunamganj	3.75	7.5	0	0	0	0
Sylhet	2.75	15	0	0	0	0