REDUCING THE IMPACT OF ENVIRONMENTAL EMERGENCIES THROUGH EARLY WARNING AND PREPAREDNESS - THE CASE OF EL NIÑO-SOUTHERN OSCILLATION (ENSO)

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IMPACTS OF THE 1997-98 EL NIÑO EVENT IN BANGLADESH

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EXECUTIVE SUMMARY
BANGLADESH

Bangladesh is one of the worst victim regions of El Niño/La Niña impacts. The existing geophysical and socio-economic settings of the country help increase both the vulnerability to and severity of those events. The country's agro-based production system depends mainly on climatic phenomena.

Bangladesh is perhaps the most unique country in the world where casualties resulting from a cyclone could rise into the hundreds of thousands, for example, the October 1970 cyclone that killed an estimated 500,000 people and the April 1991 cyclone that killed an estimated 140,000 people (see Haider, et al., 1991). Floods can devastate more than half the country causing damage in the billions of dollars. Nor'westers and tornadoes often demolish settlements and the economy in many parts of the country. Droughts destroy the country's food chain, food stock and agro-based production systems. A large number of households become homeless because of riverbank erosion. Scientists have found a correlation between El Niño/La Niña events and variability of climatic phenomena in the country, which as a result, cause those climate-related natural disasters mentioned above.

To reduce the negative impacts of climate-related disasters and to minimize the suffering of the people, the Government of Bangladesh has established a set of mechanisms including institutional arrangements for disaster preparedness and relief and rehabilitation of the areas affected or likely to be affected. For making the established mechanisms appropriately and effectively operational, an exhaustive guidebook entitled *Standing Orders on Disaster* has been designed outlining the activities of each related ministry, division and major agencies and departments. The Ministry of Relief and Rehabilitation, the Bangladesh Meteorological Department (BMD), the Disaster Management Bureau (DMB), the Space Research and Remote Sensing Organization (SPARRSO) and various other organizations both at national and local levels are associated to cope with the problems of geophysical and climate-related disasters. Still, there is a lack of scientific efforts and modern technological know-how regarding the proper management of climate-related disasters, including predictions, preparedness and mitigation measures.

Scientific research in Bangladesh relating to El Niño has not reached a satisfactory level. Research on the issue is mostly conducted through individual initiatives. The researchers use data generated by both traditional and sophisticated methods by various national and international meteorological agencies. There is evidence of historical interest in El Niño/La Niña in the country before the onset of the 1997-98 event. The real credit for meteorological and agro-meteorological predictions during ancient times goes to a mythical woman named Khana. Her verses are said to be the envy of any scientist of any time. There were several other mythical people who devoted themselves to the prediction of meteorological phenomena during ancient times. Scientifically, it was Gilbert Walker who (during the British Rule in India) identified effects of ENSO events on this sub-continent.

Bangladesh is mainly dependent on international meteorological agencies for the flow of meteorological information including predictions and transmission. SPARRSO was the first in Bangladesh to receive 1997-98 El Niño information. Although SPARRSO was a bit late in transmitting these pieces of information, they got relatively wide media coverage within the country.

This study found that El Niño's teleconnections influence the climates of Bangladesh and India. According to ENSO information and its analysis in the context of Bangladesh, El Niño is generally associated with drought, whereas La Niña results in increased rainfall and flooding.

The scientific views about the existence and strength of El Niño teleconnections to Bangladesh have been explained by Walker's observations during the 1920s. According to his observations, low atmospheric pressure prevails in the region from Australia to India when high atmospheric pressure prevails in the eastern Pacific Ocean. The scientific reason is that wind flows from a high-pressure region to a low-pressure region. As a result, huge volumes of moisture come from the Pacific Ocean to Bangladesh and India, because of the prevailing low atmospheric pressure in this area at that time. The moisture increases and causes heavy rainfall in the region of Bangladesh and India." Southern Oscillation" is the name given to the differences of the wind flow sea level pressure. It is also called "Walker Circulation." When the sea surface temperatures (SST) rise in the Eastern equatorial Pacific Ocean (i.e., an El Niño situation), then this wind flow either stops or reverses. Consequently, we see a deficit in rainfall and the possibility of drought in the region of Bangladesh. On the other hand, in the La Niña situation, Bangladesh faces heavy rainfall, floods and cyclones.

The data and information presented in this study clearly support the existence of a relationship between ENSO, drought and flood. In the study of Bangladesh monsoon rainfall, generally there is a decrease in rainfall in El Niño years in all the seasons: the pre-monsoon (March-May), monsoon (January-September), the post-monsoon (October-November) and the winter (December-February).

The time series data of yearly rainfall of four selected recording stations of Bangladesh for a period of 43 years (1950-92) show a negative and decreasing tendency in rainfall during ENSO events. In El Niño cases, the decreasing tendencies of rainfall were observed as follows: 70% at Jessore, 67% at Dhaka and Barisal, and 72% at Srimangal.

The El Niño phenomenon led to a severe drought in South Asia and a severe shortage of rainfall in Bangladesh in 1997. The analysis shows a positive correlation between the negative value of the SOI and drought in Bangladesh. On the basis of historical records, experts believe that the major famines of the region have been connected to the El Niño phenomenon.

Some interesting features have come out about teleconnections between ENSO and floods in Bangladesh. The most catastrophic floods occurred in Bangladesh in the years of 1954, 1955, 1974, 1988 and 1998. The years 1954, 1955, 1988 and 1989 were with positive SOI, whereas 1974 and 1987 were of El Niño years (e.g., negative SOI). The main El Niño occurred in the preceding years and in these years' negative anomalies was not that strong. In major El Niño years (i.e., 1951, 1957, 1972, 1976, 1982 and 1986) Bangladesh did not experience any catastrophic flooding. Thus one can come up with the hypothesis that during major El Niño years, at least during the first year (onset) of El Niño, Bangladesh can most likely be spared from catastrophic flooding. The years 1963, 1965 and 1969 were weak to moderate El Niño years and in those years moderate floods occurred in Bangladesh. Therefore, a conclusion may be drawn that during the positive and weak ENSO (positive and negative) years Bangladesh can be a victim of flood. In the case of high positive SOI Bangladesh may face severe floods.

The study shows that Bangladesh has not been struck by any catastrophic cyclone, during strong El Niño years. It is also observed that when the Southern Oscillation Index (SOI) is small (positive or negative) and when the 28.5°C isotherm stays west of 165°E longitudes, the chance of Bangladesh being hit by a cyclone is quite high.

The 1982-83 event is considered to have been one of the strongest El Niño events of the 20th century. A significant amount of excessive rainfall in the selected stations under study was observed in the previous and following years of the 1982-83 El Niño event. However, a significant deficit in rainfall was observed in both El Niño years (i.e., 1982 and 1983). This resulted in a drought in Bangladesh, which caused losses in agricultural productivity. As a result, poor and marginal farmers were badly affected. Moreover, it created a subsequent negative impact on several socio-economic conditions such as poverty, migration, social unrest, dwindling food stocks, a drop in foreign currency reserves and a slowdown in overall economic development.

It is evident from the study that Bangladesh was affected by the teleconnections of El Niño and subsequent La Niña in 1997-98. Due to the impact of the 1997-98 El Niño, Bangladesh experienced a 60% deficit in rainfall in June 1997. As a result, the southeast monsoon wind was delayed by one month and the country faced a short drought condition until June 1997. Moreover, unprecedented and unusually foggy weather during the winter and high temperatures were observed during the southwest monsoon of 1998.

A rainfall deficit was observed in all the selected stations under study, except one (Khulna). This deficit amounted to -5.4%, -20.4% and -6.7% in Cox's Bazar, Dhaka and Sylhet, respectively. Due to the deficit in rainfall and subsequent short drought during the main growing season (Aman) production decreased by 25-30% in 1997-98. This resulted in a food crisis and a high price for rice, a deficit in revenue collection, higher inflation and pressure on the 1998-99 national budget for which the government had to curtail development expenditures.

This El Niño also generated negative impacts on the poverty situation, rural-urban migration and on the environment. Subsequent La Niña impacts resulted in a severe, prolonged flood in Bangladesh in 1998, where about 51% of the total area was inundated and approximately 31 million people (26% of the total population) were affected. The total loss as a percentage of the GDP was 6.64%, which negatively influenced the economic growth rate of the country.

Only one statement was issued by the Agricultural Information Services with the title "Agricultural Weather Forecast: Actions suggested for the farmer." This was published in the *Daily News Paper* on September 15, 1997. After the appearance of El Niño impacts, a detailed statement was prepared by the government on damages, losses, and requirements of goods and services for relief and rehabilitation. A joint research project was undertaken by SPARRSO and BARC on "The Development of Models for Predicting Long-Term Climate

Variability and Consequent Crop Production as Affected by the El Niño-La Niña Phenomena." In response to proper disaster management in Bangladesh various institutional arrangements and mechanisms are now effectively operating at both the national and local levels.

Bangladesh has not yet developed powerful institutions like those in Western Europe and North America to forecast a complex climate-related process like El Niño. Nevertheless, the institutions established by the government at the national level such as the Space Research and Remote Sensing Organization (SPARRSO), Bangladesh Meteorological Department (BMD) and the Bangladesh Water Development Board (BWDB) for monitoring and forecasting disasters as well as El Niño events are trying their level best to monitor and forecast climate-related disasters. Forecasts of impacts made by them in the recent past about climate-related disasters and El Niño episodes were almost 100% correct.

Although El Niño forecasting by analogy in Bangladesh by the concerned organizations does not exactly correspond to the findings, the similarity between the two approaches are positive indeed. Since the present technology in Bangladesh is not in a position to unfold the mysterious impacts of an El Niño episode, the country has to share the latest ideas and technology from developed countries for challenging the negative impacts of El Niño/La Niña events in Bangladesh. A regular exchange of information with specialized organizations in the developed countries and the proper understanding of mechanisms of the ENSO phenomenon would enable the country to precisely forecast, plan and monitor well ahead of time to face natural disasters like cyclone drought, and flood.

In order to strengthen the concerned organizations in monitoring and forecasting climate anomalies by the Government in future, further initiatives would not only enable the country to forecast and monitor this episode more accurately but also help to reduce and mitigate the colossal impact of El Niño events through early warning and preparedness. Our study suggested a number of policy recommendations, which should be implemented in due course (see Section 5.0). For a better understanding and the undertaking of appropriate mitigation measures against possible impacts of El Niño/La Niña events, more intensive studies need to be carried out.

Top Ten Lessons

- Tele connections in Bangladesh between drought and El Niño are strong. El Niño in Bangladesh is generally associated with droughts and La Niña results in increasing rains and floods.

- Information on the ENSO warm event/cold event cycle is useful for society to minimize damage from droughts and floods.

- Bangladesh is dependent on outside sources for El Niño and La Niña forecasts and monitoring. These sources are highly essential for early warning and preparedness.

- There had been little scientific research on ENSO in Bangladesh before the 1997-98 event.

- Bangladesh has to depend on getting the latest ideas and technology from developed countries; there is a need for mutual trust between Bangladesh and industrialized countries.

- El Niño's drought impacts on downstream (out-year) development expenditures persist well after the El Niño event has ended.

- Bangladesh is becoming more prone to calamities. That is why there must be a readiness on the part of the government to institutionalize effective prevention and mitigative measures.

- Bangladesh requires education and training for personnel dealing with the prediction and monitoring of the ENSO cycle.

- Research facilities must be enhanced in order to improve impacts studies. International assistance in this regard is very important.

- A regional disaster management action plan should be established within SAARC (South Asian Association for Regional Cooperation) or some other regional framework.

Other Lessons

- Bangladesh institutions are now interested in the planning and early warning of the extremes of the ENSO cycle.

- Effective post-disaster reviews are required after each major disaster.

- The social and geophysical settings are important for Bangladesh [the country can suffer from drought and flood in same event (with El Niño or La Niña)].

- Undertake cost-benefit studies for El Niño response measures.

- Bangladesh takes into account folk wisdom in its consideration of climate extremes.

- More intensive public awareness and education programs on ENSO must be carried out in disaster-prone communities.

- Bangladesh needs to establish a permanent disaster management organization.

- Local responsibilities in dealing with ENSO's extremes need to be increased.

- The government of Bangladesh needs to support more national studies related to ENSO extremes.

1.0 INTRODUCTION

The warming of sea surface temperatures in the tropical Pacific causes changes in Pacific trade winds and ocean currents, setting off a chain reaction of weather disturbances worldwide. Scientists believe that Bangladesh is one of the most vulnerable countries in the world to El Niño or La Niña effects.[1] The country experienced very adverse El Niño effects in 1997-98, which included severe drought in various places and severe La Niña effects in 1998, which included the most devastating floods. It is thought that the country was also affected by the 1972-73, 1976, 1982, 1986 and 1994 El Niño events.[2] The country's geographical location and climatic characteristics made it vulnerable to such warm events.

The present study has been designed mainly to assess El Niño impacts and response strategies in Bangladesh and to depict the scientific views about their teleconnections. Both primary and secondary sources of data and information have been used for the study. Relevant organizations like The Space Research and Remote Sensing Organisation (SPARRSO), the Bangladesh Meteorological Department (BMD), The Disaster Management Bureau (DMB), the Water and Power Development Authority (WAPDA), concerned experts, and governmental/non-governmental officials have been consulted. A seminar/workshop, comprising participants from concerned agencies and from various government departments and non-governmental organizations, was organized to incorporate a multi-dimensional approach to the study.

The present report has been divided into five sections. Section-I deals with El Niño/La Niña impacts in relation to the country's geophysical & socio-economic settings, the existing government mechanisms for dealing with the impacts of climate-related disasters, and the country's level of scientific research on and historical interest in El Niño. The flow of meteorological information about the 1997-98 El Niño event, including the transmission of El Niño information, media coverage, etc., has been depicted in Section-II. El Niño teleconnections to various parts of the country area have been scientifically analyzed and explained in Section-III. Section-IV deals with the forecasting by analogy of El Niño/La Niña impacts. Section-V includes policy implications, recommendations and conclusions.

1.1 GEOPHYSICAL AND SOCIOECONOMIC SETTING

El Niño (or La Niña) events do not affect all regions of the world with same intensity. The vulnerability to El Niño effects depends upon the geographical setting, whereas the intensity of impacts of the events depends upon both the geographical and the socio-economic setting of a country.

1.1.1 Geophysical Features

[1] Choudhury, A.M.: Bangladesh Floods, Cyclones and ENSO, a paper presented at the International Conference on Monsoon Variability and Prediction, ICTP, 1994, pp. 8-9.

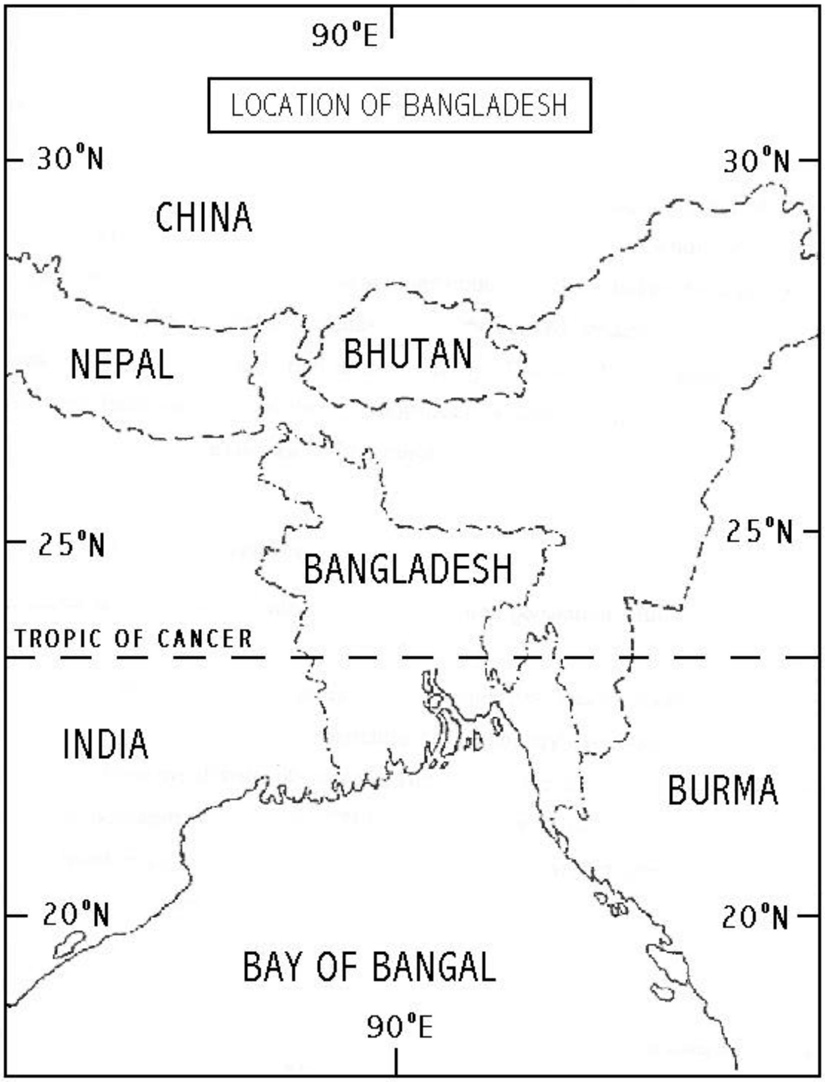
Bangladesh is a transition zone between Southwest and Southeast Asia. It forms the capstone of the arch formed by the Bay of Bengal, and because of the Tibetan plateau (massif) to the north, it is a comparatively narrow land bridge between the sub-continent of India and sub-continent of Southeast Asia. More precisely, the country stretches latitudinally between 20? 34' N and 26? 33' N and longitudinally between 88? 01' E and 92? 41' E (Map 1). Some of the biggest rivers of the world flow through the country and form the largest delta in the world. The Ganges-Brahmaputra River system forms in the Bengal Basin, a delta of 40,225 sq. km. in extent. It is, therefore, quite obvious that the monsoon rains, the rise and fall of river levels, floods, alluvia and dilluvia and changes in river courses form the substance of both the cultural and physical geography of the area.

Geological studies suggest that, due to continental drifts and plate tectonic movements, the Gondwana part of the single continental mass Pangaea[3] underwent several changes through the processes of subduction, collision and sea-floor spreading. In the Oligocene Period (38 to 26 million years ago), some time after the plates collided, a portion of the northern part of the Indian plate fractured and sank below sea level. This portion was gradually filled up to form the eastern part of the Bengal Basin (Map 2).[4] Bangladesh is, therefore, formed on a mass of sediments washed down from the highlands on three sides of it, and especially from the Himalayas, where slopes are steeper and the rocks less consolidated. The greater part of this land-building process must have been due to the Ganges and Brahmaputra Rivers. It is mainly a deltaic land having hundreds of big and small rivers, Haors (large lake-like bodies), Baors, Bils, etc., all over the country and some hills and mountains in the northeastern, eastern and southeastern parts of the country. The country has the longest continuous sea beach in the world (about 144 km).

[3] It is thought that most of the earth's land formed a single continental mass, called Pangaea, surrounded by one ocean, called Panthalassa I during the early Triassic Period, (225 to 190 million years ago).

[4] Harun Er: *Geography of Bangladesh*. University Press Ltd, Dhaka, 1991, pp. 3-9.

Map-1



Source: Rashid, Harun Er.: *Geography of Bangladesh*. University Press Ltd., Dhaka, 1991, p.2.

A vast amount of water (1073 million acre feet/year)[5] flows through Bangladesh of which 870 million acre feet/year flows into the country from India. This brings about 1.5 billion metric tons of sediments into the country every year.[6] The climate of the country is characterized by high temperature, heavy rainfall, often-excessive humidity and a fairly marked seasonal

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5 One acre-foot equals 1233.48899958 cubic meters.

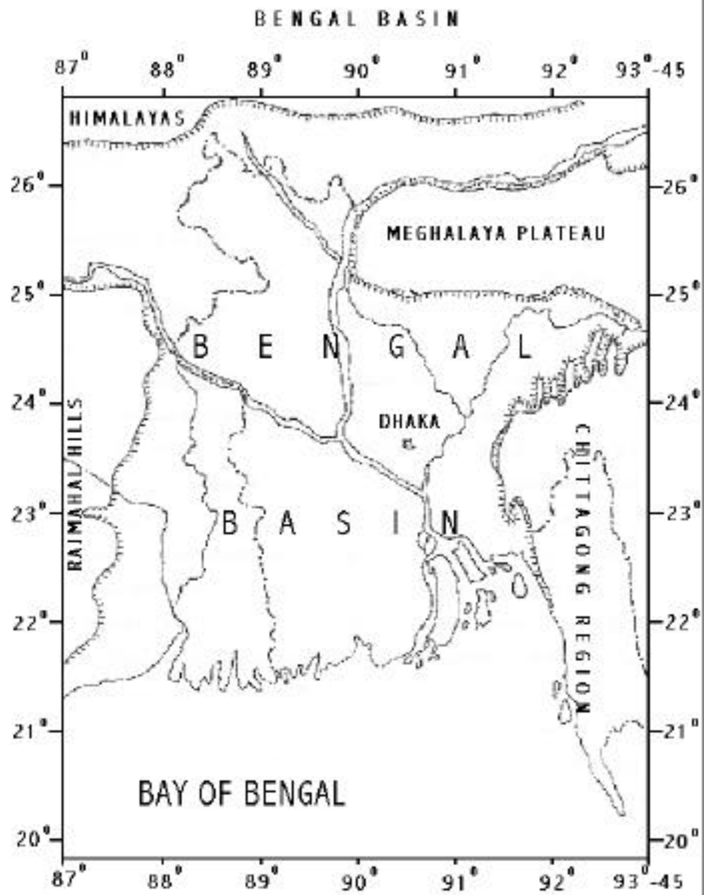
6 Yusuf, Sayed Anwar: Disaster Preparedness and Management in Bangladesh. A research mimeo, Dhaka, 1991.

variation (i.e., tropical climate). The country is very rich in bio-diversity.[7] Due to its geographical location, landforms and a funnel-shaped seashore, Bangladesh is considered to be one of the most vulnerable disaster- prone countries of the world.

1.1.2 Socio-economic features

Bangladesh is an agrarian country with 120 million inhabitants within an area of 143,999 sq. km. of land. By religion, the country's population consists of 86.6% Muslims, 12.1% Hindus and 1.3% Christians and other cultural minorities. Nearly four-fifths of the people depend, directly or indirectly, upon agriculture. The country's agro-based production system depends mainly on climatic phenomena. High population density, a rapid rate of population growth, low per-capita income (only $273 US a year), mass poverty, low literacy rate, high rate of unemployment, malnutrition (67% of the total population), weak economy, etc., are the major socio-economic features of the country.[8]

Many of the people of the country have some deep-rooted religious superstition regarding natural disasters. They believe that God imposes all disasters, especially climatic disasters as a result of our outrageous activities.[9]



Map-2

Source**:** Rashid, Harun Er: *Geography of Bangladesh*. University Press Ltd., Dhaka, 1991, p.8.

7 Imam, Kazi Hasan: *Environmental Protection and Sustainable Development*: Bangladesh Perspectives. Paragon Publishers, Dhaka, 1999, p. 71.

8 ibid, pp. 53-54.

9 Imam, Kazi Hasan: Naturkatastrophen und Armut der Menschen ? Ansaetze praeventiver Umweltverwaltung in Bangladesch: *Entwicklungsrecht und sozial-oekologische Verwaltungs-partnerschaft*, Schrieftreihe der Hochschule Speyer, Band 116, Duncker and Humblot, Berlin, 1994, pp.199-201; Imam, Kazi Hasan: *Environmental Protection and Sustainable Development: Bangladesh Perspectives*. Paragon Publisher, Dhaka, 1999, pp. 176-177.

1.1.3 Government Mechanisms for Dealing with the Impacts of Climate-Related Disasters

To reduce the negative impacts of climate-related disasters and minimize the sufferings of the people, the Government has established a set of mechanisms including institutional arrangements for disaster preparedness and relief and rehabilitation of the area affected or potentially affected. For making the established mechanisms appropriately and effectively operative, an exhaustive guidebook entitled, *Standing Orders on Disaster*, has been designed to outline the activities of each related ministry, division and major agencies and departments. Considering the importance of the effects of climate-related disasters in Bangladesh, the government has also taken initiatives to formulate a comprehensive National Policy of Disaster Management and a National Disaster Management Plan. To deal with climate-related disasters by the entire government machinery, the National Disaster Management Council meets the requirement of clear policies and provides scope for proper implementation of the policy directives. A High Level Inter-Ministerial Disaster Management Coordination Committee gives decisions for implementation of these policies and policy directives. The Committee incorporates the role of the Ministry of Disaster Management and Relief as the responsible line Ministry, provides for integration of the Armed Forces and reflects the crucial role of Disaster Management Committees at Union, *Thana* and District levels. The Bangladesh Cyclone Preparedness Program (CPP) has about 30,000 volunteers to come to the rescue of the affected people in the coastal areas during cyclones.

The Bangladesh Space Research and Remote Sensing Organization (SPARRSO) and the Bangladesh Meteorological Department (BMD) are responsible for providing forecast information about climate-related disasters in the country. The Bangladesh Water Development Board (BWDB) is responsible for forecasting water-related disasters like floods and their possible impacts.[10] These organizations are also responsible for conducting research about climate-related disasters and their effects on society and environment.

The government media, Radio Bangladesh and Bangladesh Television, play the prime role in transmitting the forecast information, tracking the courses and chalking out elaborate programs on awareness development about preparedness and the possible effects of potential disasters. The National Dailies also play a vital role in these respects.

1.2 Climate-Related and Other Natural Hazards Affecting the Country

During the 1997-98 El Niño event, climate anomalies with significant socio-economic impacts were experienced outside the tropical Pacific. El Niño-related natural disasters are of global concern, have their most severe impacts on vulnerable communities, and can contribute to increasing poverty.[11]

[10] Karmaker, Samarendra: 1997-98 El Niño With Responses and Plans: Bangladesh Perspectives. BMD, Dhaka, 1999, p. 9.

[11] Hossain, Md. Ershad: Climate Related Hazards in Bangladesh with Reference to the Level of Scientific Research Relating to El Niño. BMD, Dhaka, 1999, p. 10.

Bangladesh is perhaps the only country in the world where casualties due to a cyclone could rise into the hundreds of thousands. Floods can devastate more than half the country causing damage in the billions of dollars. Nor'westers and tornadoes often demolish the economy and settlements in many parts of the country. Droughts destroy the country's food chain, food reserves and agro-based production systems. A large number of households become homeless as a result of riverbank erosion. Earthquakes cause severe damage to human settlements. The climate-related and other natural disasters affecting the country have been listed below in order of concern:

- Floods
- Tropical cyclones and associated storm and tidal surge
- Nor'westers and tornadoes
- Erosion
- Drought
- Earthquakes
- Siltation
- Salinity
- Desertification

Scientists have found a correlation between El Niño/La Niña events and the variability of climatic phenomena in Bangladesh. They have suggested that further research needs to be undertaken in this respect.

1.3 Level of Scientific Research on El Niño

El Niño (or La Niña) has drawn worldwide attention very recently. The world's experts have differences of opinions regarding the origin and impacts of El Niño or (La Niña) events. Walker and Bliss (1932) believed that the periodic warming and cooling of the southern Pacific Ocean, which produces El Niño or La Niña effects, is actually related to a phenomenon known as Southern Oscillation. According to their view point, "when pressure is high in the Pacific Ocean, it tends to be low in the Indian Ocean from Africa to Australia; these conditions are associated with low temperatures in both these areas and rainfall varies in the opposite direction to pressure. Conditions are related differently in winter and summer, and it is therefore necessary to examine separately the seasons of December to February and June through August."[12] The Southern Oscillation is a seesaw oscillation of pressure in the tropics between the Indian and the West Pacific Oceans on one hand and the Southeast Pacific Ocean on the other. This is an atmospheric phenomenon, whereas El Niño is an oceanic phenomenon.[13] Bjerknes considered it to be an event of ocean-atmospheric coupling.[14] An El Niño event is basically manifested by a reduction in coastal upwelling of cold, deep ocean water to the surface. Some scientists have argued that this quasiperiodic appearance of warm

[12] Walker, G. T. and Bliss, E. W: World Weather V., Memories of the Royal Meteorological Society 4, 1932, pp. 53-84.

[13] Choudhury, A. M: Bangladesh Floods, Cyclones and ENSO. A paper presented at the International Conference on Monsoon Variability and Prediction, ICTP, 1994, p. 2.

[14] Bjerknes, J: Atmospheric Teleconnections from the Equatorial Pacific, *Mon. Weather Rev*. 97, 1969, pp. 163-172.

surface water in the upwelling regions is triggered by various factors such as continental drift, tectonic movement of ocean plates, earthquakes or volcanic eruptions on the ocean's bed. Greenhouse effects and global warming has also been interpreted as triggering factors of El Niño or La Niña event.[15] Some scientists explained it to be a combined effect of southeast trade winds, variations of sea surface temperatures (SSTs) and Coriolis Forces.[16] Von Humboldt (in 1802) presented his Peru-Current Theory, which is popularly known as the Humboldt Theory, to explain the event. Klaus Wyrtki tried to explain the phenomena with his Equatorial Kelvin Wave Theory.[17] Mark Cane stressed the importance of Rosby Wave Propagation from the eastern to the western Pacific.[18] Numerical experiments are being carried out on a hierarchy of coupled models of the atmosphere and the ocean and encouraging results have been obtained toward El Niño predictions.

Many scientists had previously speculated that El Niño was caused by disturbances along the earth's crust, since earthquakes and volcanic eruptions often preceded the phenomenon.[19] But new work with computer models and sophisticated monitoring equipment suggests that the current is not triggered by geological disruptions. Instead, it is part of a naturally occurring cycle resulting in the interactions between the sea and the skies of the equatorial Pacific. Scientists say that the latest monitoring efforts have helped them make more reliable El Niño predictions. Some scientists think that the decrease in tropical cyclone numbers frequency and intensity in recent decades might be interpreted as evidence that predictions of more and stronger cyclones accompanying warmer SSTs are wrong.[20]

Scientific research in Bangladesh relating to El Niño has not reached a satisfactory level. Research on the issue is mostly conducted on individual initiatives. The researchers use data generated through both traditional and sophisticated methods by various national and international meteorological agencies. In Bangladesh, studies have been conducted on "A Climatological Study of Bangladesh and the Possible Correlation with El Niño/Southern Oscillation" in 1993, "Bangladesh Floods, Cyclones and ENSO" in 1994, "Theory of El Niño" in 1994, "El Niño Southern Oscillation and Rainfall Variation Over Bangladesh" in 1996, "ENSO and Monsoon Rainfall Variation Over Bangladesh" in 1994, "El Niño and La Niña Cycle" in 1998 etc., with individual initiatives. SPARRSO took up a research project in 1999 entitled "Development of Models for Predicting Long Term Climate Variability and Consequent Crop Production as Affected by El Niño-La Niña Phenomena." Besides, several studies have been conducted directly on the after effects of El Niño-La Niña phenomena.

Through these studies, scientists identified that the devastating flood of 1974 had occurred due to the 1972 El Niño event, and the severe floods of 1987 and 1988 had occurred because of the 1986 El Niño event. They had predicted during the 1997 El Niño event that a La Niña

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15 World Disaster Report, 1999, p. 16.

16 Ali, Dr. Anwar: El Niño. *Journal of Remote Sensing*, SPARRSO, No. 1, Dhaka, 1998, pp. 12-16.

17 Wyrtki, K: El Niño ? The Dynamic Responses of the Equatorial Pacific Ocean to Atmospheric Forcing. *J. Phys. Oceanographer*. 5, 1975, pp. 572-584.

18 Cane, M. A: El Niño. Annual Review; Walker, G. T. and Bliss, E. W: World Weather V., Memories of the Royal Meteorological Society 4, 1932, pp. 53-84.

19 *International Encyclopaedia of Sustainable Development*. Vol. 2, Anmal Publication Pvt. Ltd., 1998, p. 108.

20 *International Encyclopaedia of Sustainable Development*. Vol. 5, Anmal Publication Pvt. Ltd., 1998, p. 25.

situation could develop after May 1998 and Bangladesh might experience severe flooding.[21] Scientific research found a negative correlation with tropical cyclones over the Bay of Bengal and a correlation of ENSO events with rainfall deficits over India and Bangladesh[22] during the 1951-87 period.

1.4 Historical Interests of El Niño before the Onset of the 1997-98 El Niño Event

There is no authentic historical record about when and how the first El Niño occurred, but geologists assume that El Niño began occurring since the Tertiary Period (2-65 million years ago).[23] Recorded historical evidence proves that the first El Niño event occurred in 1925-26, although the term El Niño was not used in the record (except in association with impacts in Peru). The term El Niño came into worldwide use only recently. It is thought that El Niño has immense influences on monsoon climatic variability. Historical evidence shows that monsoon phenomena have been under study on this sub-continent since ancient times. For example, monsoon phenomena have been mentioned in the holy Ramayana and Mohabharata and in other Vedic books. In the book Artha-Sastra (Science of Economics) written during the reign of Chandragupta Maurya (321-296 B. C.) by his Minister Kautilaya, there is mention about the amount of rains at different places, indicating that they had knowledge about rainfall measurements. The astronomer Varaha Mihir (505-587 A. D.) used to predict rains. Astronomer Arya Bhatta and Brahmagupta also studied the monsoon. The famous Sanskrit poet Kalidas composed poems out of monsoon clouds as depicted in his Meghdoot (Messenger of Cloud) and Ritusamahara (Cycle of Seasons). However, the real credit for the meteorological and agro-meteorological predictions during the ancient times goes to a mythical woman named Khana. Her verses are said to be the envy of any scientist at any time. Scientifically Gilbert Walker, during the time of British rule in India, identified effects of ENSO events in this Sub-continent.[24] Sikka in 1980 was apparently the first to suggest that during El Niño years the Indian monsoon performs below normal. Parthasarathy and Pant observed in 1985 that the Indian monsoon shows a good correlation between a strong SOI (cold event) and a good monsoon year.[25] Mandal conducted a study in 1989 on the relationship between tropical cyclones and rainfall over the Bay of Bengal and ENSO events. Chowdhury also conducted the same type of study in 1992. Ahmed in 1993 predicted that in general the Bangladesh monsoon shows a decrease in rainfall in El Niño years in all seasons.[26]

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[21] Choudhury, Dr. A. M: El Niño and La Niña Cycle. Bangladesh Space Research and Remote Sensing Organization, Dhaka, 1997, pp. 3-4.

[22] Bangladesh Space Research and Remote Sensing Organization: Annual Report 1995-96. SPARRSO, Dhaka, 1996, pp. 9-10; Ahmed, A. S. M. Sabbir et al: El Niño Southern Oscillation and Rainfall Variation Over Bangladesh. SPARRSO, Dhaka, 1995, pp. 157-158.

[23] Ali, Dr. Anwar: El Niño. *Journal of Remote Sensing*, SPARRSO, No. 1, Dhaka, 1998, pp. 12-18.

[24] Choudhury, A. M: Bangladesh Floods, Cyclones and ENSO. Paper presented at the International Conference on Monsoon Variability and Prediction, ICTP, 1994, pp. 2-4. and ibid. p. 10.

[25] Parthasarathy, B. and Pant G. B: Seasonal Relationships between Indian Summer Monsoon Rainfall and the Southern Oscillation. *Journal of Climatology* 5, 1985, pp. 369-378.

[26] Ahmed, A. S. M. S: A Climatological Study of Bangladesh and Possible Correlation with El Niño/Southern Oscillation, M. Sc. Dissertation, and University of Dhaka, 1993.

Today, experts opine that the ability to accurately predict the coming of El Niño could have a considerable impact on human development. After a scientific study, ERFEN (Estudio Regional del Fenómeno de El Niño) experts say, "By tracking ocean temperature, salinity levels and wind patterns, they can now tell when El Niño is approaching several months before it hits South America." National Center for Atmospheric Research (NCAR) Senior Scientist Michael Glantz says, "If you can forecast El Niño, you can shed light on when to expect droughts and floods in various countries."[27] Khana, Ghagh, Varaha Mihir, Ahamika Duck, and Bhandori, etc., the most famous mythical persons in this sub-continent, told of these conditions 3-14 centuries ago. They did not utter the words El Niño or La Niña in their sayings, but they rightly predicted the phenomena.[28] Khana's sayings are especially considered to be the most important, most scientific and most talked about mythical worlds in Bangladesh and also in this region. Some of her sayings have been quoted and analyzed as follows:

Basically, Khana's sayings are based on astronomical readings. She did not correlate her forecasts to events like El Niño or La Niña episodes. Most of her meteorological readings seem to be very much based on local weather. But today's scientists found strong correlations between El Niño and La Niña episodes and local climatic behavioral patterns.[29] What she told many centuries ago during the 9th lunar day of the bright fortnight in the Bengali month of Ashar (June-July), "If the month of Choitra (March-April) of a year experiences cold weather and the month of Baishakh (April-May) is marked by storms and hailstorms and the sky remains free from clouds, the year will receive sufficient rains; if rainfall is torrential, the year may experience drought; if rainfall is intermittent, the year may experience heavy flooding; if moderate rainfall occurs, crops will grow in abundance and if the sky remains clear and bright during sunset on that day, the year will experience salvation." Today's experts have found scientific bases behind these predictions. She also predicted that:

> If southwest monsoon winds blow at the beginning of the year, the year will be marked by sufficient rainfall.

It means that when the southwest wind blows from the Bay of Bengal, it carries a lot of moisture and, as a result, plenty of rainfall occurs in summer (the beginning of the year). Khana also predicted these climatic phenomena in another way. Khana's predictions about drought were the following:

> If southern winds blow during rains, the rain will stop and flood will decrease.

Bhandori, another mythical person of this sub-continent predicted as follows: "If Southwest winds blow for seven days continuously, the country will experience severe drought." But Khana's forecasts directly about drought were as follows:

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[27] *International Encyclopaedia of Sustainable Development*. Vol. 2, Anmal Publication Pvt. Ltd., 1998, p. 109.
[28] Nawaz, Dr. Ali: *Khana's Sayings: Agriculture and Bengali Culture*, Bangladesh Agricultural Research Council, Dhaka, 1989, Vol. two, pp. 7-53.
[29] Karmaker, Samarendra: 1997-98 El Niño Event with Responses and Plans: Bangladesh Perspectives. BMD, Dhaka, pp. 2-7.

> If the sky remains cloudy during the day and clear at night, the country will experience drought.
>
> If hot weather in the month of Poush (December-January) and cold weather in the month of Baishakh (April-May) prevail and heavy rainfall occurs at the beginning of the month of Ashar (June-July), the months Shraban-Bhadra (July-September) will experience drought in that year.

Khana had very peculiar insights about the duration of rainfall in different seasons of the year. According to her:

> If it is foggy during the month of Poush (December-January), there will be rain in the month of Baishakh (April-May) for the days exactly corresponding to the number of foggy days in Poush; if rain begins on Saturday, it will continue up to seven days; if it begins on Tuesday, it will continue up to three days.

Varaha Mihir also predicted these climatic phenomena in a different way: "If the month of Poush (December-January) does not experience excessive cold weather, the year will receive sufficient rains." According to Khana, "by observing the weather of the month of Poush (December-January), the weather of the whole year can be predicted. The weather condition of the first two and a half days of the month of Poush (December-January) is the indicator of every month of the next year." She had devised a process of predicting a weather calendar, which, today, is considered to be very much scientific in nature.[30]

Some other predictions of Khana about floods, rains and agricultural production were as follows:

> If Northern wind blows during the month of Shraban (July-August), the year will experience severe floods.
>
> If rain occurs in the month of Choitra (March-April) and cold weather prevails in the month of Baishakh (April-May) in a year, scarce rainfall will occur in the new year.
>
> The more the mangoes grow, the more the floods will occur; the more the jack-fruits grow in a year, the more the paddy will grow in that year.

It is true that the scientists on this sub-continent did not correlate the climatic phenomena to named events like El Niño or La Niña historically, but they predicted and recorded them. These days, scientists are well-equipped with modern tools and technologies to predict future events and trace out the correlations of past events. It is remarkable that the great Bengal famine years of 1770, 1940-41, 1943 and 1974 were El Niño years.

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[30] Nawaz, Dr. Ali: *Khana's Sayings: Agriculture and Bengali Culture*, Bangladesh Agricultural Research Council, Dhaka, 1989, Vol. 2, p. 39.

2.0 Flow of Meteorological Information on the 1997-98 El Niño Event

As El Niño is a climate-ocean fluctuation centered in the tropical Pacific with important consequences for worldwide weather conditions, the WMO, NOAA, Bureau of Meteorology in Australia, the Japan Meteorological Agency (JMA) and many other meteorological agencies or departments both at the national and international levels had shown their keen interest in this phenomenon. Advanced, dynamic and statistical models are now widely used to predict climate-related phenomena like El Niño. Super computers are required to run those models. Since observations from the tropical Pacific are essential for studying and forecasting El Niño events, NOAA operates a network of buoys that measures ocean temperatures, currents and winds in the equatorial band (e.g., wave guide). These buoys transmit data on a regular basis. Researchers and forecasters around the world can receive those data for real-time use. The BMD has recently acquired some modern facilities to receive these kinds of data.

A perfect forecast of El Niño's occurrence was, in fact, not available up to early October 1996. But WMO reported that by late 1996, La Niña conditions had peaked and climate forecasters were already turning their attention to the possibility of a new El Niño forming in 1997. By early 1997, most numerical models and empirical forecast schemes had started to indicate the inception and evolution of a possible El Niño episode. The forecast came to pass with unusually strong El Niño conditions dominating the climate throughout much of the second half of 1997 and into early 1998. This "El Niño of the 20th Century" then abruptly gave way to moderate La Niña conditions by mid-year. The sequence of events starting in early 1996 is well documented (Barnston, et al., 1999). The forecasts after mid-1997 from most of the major prediction centers indicated that El Niño conditions would continue through the March-May period of 1998, followed by a weakening of the warm episode. Some models by spring 1998 indicated a switch to a La Niña event beginning at some point between July and September 1998. On the basis of these forecasts, BMD and SPARRSO predicted above normal rainfall for the 1998 Southwest monsoon season, and the media of Bangladesh circulated this projection.

As El Niño events have worldwide implications, the 1997 event caused severe drought in Southeast Asia and severe rainfall shortages in Bangladesh in the 1997 post monsoon season, which had been forecast by the BMD and SPARRSO and published in the daily newspapers by Ministry of Agriculture.[31] As a result, different agencies came to know it mostly from the media. In this regard a report was published by a national daily (*Muktakantha*) in November 1997 stressing the apprehension of drought in Bangladesh as an El Niño impact. SPARRSO continued to supply daily weather reports based on satellite and other information to the Ministry of Agriculture and the Prime Minister's Office. Interest of the Bangladesh Government in this subject arose after a report was published sometime in April 1998 in a national daily newspaper (*The Daily Independent*) on the possible impacts of El Niño on crop production.

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[31] The Government of the People's Republic of Bangladesh: Advisory to Farmers, Agriculture Information Service, *The Daily Ittefaq*, 13 September 1997 and *Ajker Kagoj*, 15 September 1997.

2.1 Agencies First Heard About El Niño Development

In 1997 El Niño developed very rapidly during April and May and reached a high intensity by June. In November 1997 the WMO began issuing regular monthly statements on El Niño to ensure that the most effective and accurate information was made available in a timely manner to all concerned. The Bangladesh Meteorological Department claimed that they were the first to receive the El Niño information through the WMO and the Bureau of Meteorology (Australia),[32] but paper clippings and other documents proved that SPARRSO had been the first to receive the El Niño information in Bangladesh. Basically, the BMD had been the main agency to receive and forecast this sort of information, although SPARRSO shares the responsibility.

2.2 Transmission of El Niño Information

Information about the event was obtained by SPARRSO and the BMD from the WMO and Bureau of Meteorology, Australia, as a monthly report and then transmitted to the media as statements. The information was published in daily newspapers. The media first reported it, covering its concepts, existing theoretical explanations about its origin and its worldwide after-effects. Experts working in various government departments were also trying to develop a forum on the issue in order to build public awareness and to draw the attention of government authorities. Seminars and workshops were also held on El Niño. At last, by May 1998, the government took a keen interest in it.

It should be noted here that many of our national newspaper dailies started publishing news on El Niño during 1997. However, as mentioned earlier, *The Daily Star* and *Muktakantha* published news about El Niño and its effects in the month of November 1997. The Ministry of Agriculture published their handouts about less rainfall in September 1997, but they did not mention El Niño in their handouts. SPARRSO published its reports through *The Daily Star* on 6 November 1997 noting that El Niño had started in the Pacific Ocean in March 1997, and its influence had reached Bangladesh in June 1997. Because of its effects, the country would experience less rainfall in the 1997-98 period. Although SPARRSO came to know about El Niño much earlier from the foreign media, they were late in publishing their reports. For creating awareness and undertaking timely measures, our National Disaster Management Committee should have heard about El Niño from the meteorological department and SPARRSO, but our meteorological department did not pay any attention to El Niño's effects in Bangladesh.

2.3 Media Coverage on El Niño over Time

The media, both domestic and foreign, gave positive coverage to the impacts of El Niño in Bangladesh. Radio Bangladesh and Bangladesh Television concentrated their coverage mainly on the aftereffects of this El Niño event in the country. The national dailies gave wider

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[32] Karmaker, Samarendra: 1997-98 El Niño with Responses and Plans: Bangladesh Perspectives. BMD, Dhaka, 1999, p. 9.

coverage on the issue. Some of these headlines, names of media and dates are presented below:

a. Advisory to Farmers: Agriculture Information Service, *The Daily Ittefaq*, on 13 September 1997.

b. Advisory to Farmers: Agriculture Information Service, *The Ajker Kagoj*, on 15 September 1997.

c. SPARRSO: El Niño, *The Daily Star*, on 6 November 1997.

d. Bangladesh Facing El Niño Effect: Apprehension of Drought, *The Muktakantha*, on 12 November 1997.

e. El Niño Phenomenon Blamed for Tropical Floods, Drought in 1997, *The Daily Star*, on 20 December 1997.

f. Hot Ocean Current ? El Niño Changing World Weather.

g. Disaster Signals of Weather: Bangladesh Submerged by Flood Waters, China Facing Flood, Some Other Countries of the World Experiencing Droughts ? The Nature has been Changing Its Characteristics.

h. Is Dhaka in Grip of El Niño? *The Bangladesh Observer* in April 1998.

i. El Niño is at End in the Pacific Ocean: La Niña Begins ? Bangladesh Will Face Torrential Rains, Severe Floods and Storms, *The Daily Dinkal* on 6 July 1998.

j. Effects of El Niño Being Studied to Help Farmers Face Weather Change, *The Daily Star* on 6 July 1998.

k. El Niño/La Niña: Wreaking Havoc across the World ? by Md. Asadullah Khan in *The Daily Star* on 11 July 1998.

l. "El Niño/La Niña: Droughts, Floods, Epidemics, Famine around the World", by Hasibul Faruqe Chowdhury in *The Bhorer Kagoj* on 13 July 1998.

m. Ganges Basin Braces for Deadlier Floods ? by Mustafa Kamal Majumder, *The Bangladesh Observer* on 19 July 1998.

n. Will Bangladesh Face the Threat of La Niña Weather Phenomenon? ? by Quamrul Islam Chowdhury, *The Daily Star* on 20 July 1998.

o. Influences of La Niña: Excessive Rainfall in Himalayan Regions ? by Rashed Ahmed in *The Daily Sangbad* on 12 September 1998.

p. Prolonged Flood Likely, Say Experts ? by Mustafa Kamal Majumder, *The Daily Independent* on 5 October 1998.

q. La Niña: Possibility of Scattered Rainfall in this Month, *The Daily Janakantha* on 06 October 1998.

The media compared the 1997-98 El Niño event with those of the previous events of the century. They also compared its after-effects with those of the previous ones. Experts predicted that the 1998 flood would be a prolonged one, which would severely affect the economy, society and environment. There was also coverage in the international news media on the subject.

2.4 Previous Mention of El Niño in Media Before Mention of the 1997-98 El Niño

Though the phenomena related to El Niño were scientifically studied by Sir Gilbert Walker, Director General of Observatories of the then-Indian Meteorological Department in the 1920s, they were ignored by the meteorological community of the world in general and this region in particular. The previous mentions of El Niño before the mention of 1997-98 El Niño in the media were mainly in the form of causes and effects of local climate variations. Researchers and experts worked on it, and their findings were published by different national and international agencies. Perhaps *The Daily Star* gave the first wide media coverage on the issue with the headline "ENSO and Monsoon Rainfall Variation Over Bangladesh" on 23 November 1994. People came to know about previous El Niño events, mainly through various international news media. They also came to know about it through publications of research works, seminars and symposia conducted by local experts.

3.0 Teleconnections

3.1 Scientific Views About the Existence and the Strength of El Niño Teleconnections to the Country Area

El Niño teleconnections influences the global climate in different regions in different ways. In Bangladesh, El Niño is generally associated with drought, whereas La Niña, which corresponds to the positive value of the Southern Oscillation Index (SOI), results in increased rainfall leading mostly to torrential rainfall (deluges).[33]

Scientific views about the existence and strength of El Niño teleconnections to Bangladesh may be explained by Walker's observations made during the 1920s. He observed worldwide meteorological factors, especially rainfall, and tried to identify a relationship between rainfall in India and climate anomalies in other parts of the world. According to his observations, low atmospheric pressure prevails in the region from Australia to India, when high atmospheric pressure prevails in the eastern equatorial Pacific Ocean. Since wind flows from

[33] Syed Anwar, Participant of 30th SSC. Comments on the seminar of Natural Disaster with special reference to El Niño held on 5 Sept. 1999, BPATC, Savar, Dhaka.

high pressure to low pressure, huge volumes of moisture come from the Pacific Ocean to Bangladesh and India; it causes heavy rainfall in this region. Year by year there is a variation in the wind flow. Today this process is measured by recording between Darwin and Tahiti. Gilbert Walker named these differences of pressure-driven wind flow as the Southern Oscillation. However, when the sea surface temperatures rise in the eastern Pacific Ocean, then this surface wind flow stops or reverses. Consequently, we see a deficit in rainfall and possibility of drought in our region. This is the effect of El Niño in our region. On the other hand, in the La Niña situation (the opposite of El Niño) we face heavy rainfall, flood and cyclones.[34]

3.1.1 Drought and Flood in Bangladesh and ENSO

The existing relationship between ENSO and drought and flood in Bangladesh can be supported by statistical analysis and interpretation. A study on the Indian Monsoon (Parthasarathy and Pant, 1985) has shown that there is a good correlation between a strong positive value of the SOI (cold events) and good monsoon years.[35] Another study on Bangladesh monsoon rainfall (Ahmed, 1993) has shown that in general there is a decrease in rainfall in El Niño years in all seasons: the pre-monsoon (March-May), the monsoon (June-September), the post-monsoon (October-November) and the winter (December-February).[36]

The time series data of yearly rainfall for four recording stations in Bangladesh for a 43-year period (1950-92), presented in Table 1a, b, c and d, show a negative and decreasing tendency in rainfall during ENSO events. In El Niño cases, the decreasing tendencies of rainfall were observed 70% at Jessore, 67% at Dhaka and Barisal and 72% at Srimangal.[37]

i. Similarly, in the **Pre-monsoon Period**, rainfall variations show a decreasing tendency in all of the four stations in most (64.44%) of the El Niño events. On an average the decreasing tendency in rainfall at Jessore, Dhaka, Barisal and Srimangal was by 50%, 78%, 60% and 70% of El Niño cases, respectively (Table 1a).

ii. **The Monsoon Period:** A decreasing tendency in rainfall variations was also observed in most of the El Niño cases in all the stations except Dhaka. Data show that the decreasing tendency in rainfall at Jessore, Dhaka, Barisal and Srimangal was 80%, 37.5%, 60% and 66.66%, respectively, during El Niño events. On average, the decreasing tendency in rainfall was 61% for all the four stations (Table 1b).

iii. **The Post Monsoon Period:** A decreasing tendency in rainfall variations at Jessore, Dhaka, Barisal and Srimangal was 60%, 77.77%, 70% and 80% of the El Niño cases,

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34 Choudhury, Dr. A.M., "El Niño, El Niño Cycle," SPARRSO, Dhaka, 1997.

35 Parthosarathy, B. and Part, G; B. (1985); Seasonal Relationships between Indian summer Monsoon Rainfall and the Southern Oscillation. *Journal of Climatolog*y 5, 369-78.

36 Ahmed, A.S.M.S., A Climatological Study of Bangladesh and Possible Correlation with El Niño/Southern Oscillation. M.Sc. Dissertation, University of Dhaka, 1993.

37 A.S.M.S. Ahmad, A.A. Munim, Q.N. Begum and A.M. Choudhury; El Niño-Southern Oscillation and Rainfall Variation over Bangladesh: *Mausam* 47,2, pp. 157-162, 1996.

respectively. On average, rainfall variations show a decreasing tendency by 69.44% of the cases for all the stations (Table 1c).

iv. **The Winter Period:** During this low rainfall period, all the four stations show a decreasing rainfall tendency in most of El Niño cases. For the four stations on average, the decreasing tendency in rainfall appeared in 73% of El Niño cases (Table 1d).

Table 1a. Pre-monsoon Rainfall Variations (1950-92)

Station	No. of El Niño years accounted	Negative or decreasing tendency event (In % of total El Niño years)	Positive or increasing tendency events (In % of total El Niño years)	Zero or no variation tendency events (In % of total El Niño years)
Jessore (1950-92)	10	50%	30%	20%
Dhaka (1950-92)	9	77.77%	22.22%	0
Barisal (1950-92)	10	60%	30%	10%
Srimangal (1950-92)	10	70%	20%	10%

Source: A.S.M.S. Ahmed, A.A. Munim, Q.N. Begum and A.M. Choudhury; El Niño Southern Oscillation and Rainfall Variation over Bangladesh: *Mausam* 47,2 pp. 157-162, 1996. Table 2, p.159.

Table 1b. Monsoon Rainfall Variations (1950-92)

Station	No. of El Niño years accounted	Negative or decreasing tendency event (In % of total El Niño years)	Positive or increasing tendency events (In % of total El Niño years)	Zero or no variation tendency events (In % of total El Niño years)
Jessore (1950-92)	10	80%	20%	0%
Dhaka (1950-92)	8	37.5%	50%	12.5%
Barisal (1950-92)	10	60%	40%	0
Srimangal (1950-92)	9	66.66%	33.33%	0

Source: A.S.M.S. Ahmed, A.A. Munim, Q.N. Begum and A.M. Choudhury; El Niño Southern Oscillation and Rainfall Variation over Bangladesh: *Mausam* 47,2 pp. 157-162, 1996. Table 2, p.159.

Table 1c. Post-monsoon Rainfall Variations

No. of El Niño years accounted	Station	Negative or decreasing tendency event (In % of total El Niño years)	Positive or increasing tendency events (In % of total El Niño years)	Zero or no variation tendency events (In % of total El Niño years)
10	Jessore (1950-92)	60%	40%	0
9	Dhaka (1950-92)	77.77%	22.22%	0
10	Barisal (1950-92)	70%	30%	0
10	Srimangal (1950-92)	80%	10%	10%

Source: A.S.M.S. Ahmed, A.A. Munim, Q.N. Begum and A.M. Choudhury; El Niño Southern Oscillation and Rainfall Variation over Bangladesh: *Mausam* 47, 2 pp. 157-162, 1996. Table 2, p.169.

Table 1d. Winter Rainfall Variations

Station	No. of El Niño years accounted	Negative or decreasing tendency event (In % of total El Niño years)	Positive or increasing tendency events (In % of total El Niño years)	Zero or no variation tendency events (In % of total El Niño years)
Jessore (1950-92)	10	80%	20%	0
Dhaka (1950-92)	9	67%	22%	11%
Barisal (1950-92)	10	90%	10%	0
Srimangal (1950-92)	9	56%	44%	0%

Source: A.S.M.S. Ahmed, A.A. Munim, Q.N. Begum and A.M. Choudhury; El Niño Southern Oscillation and Rainfall Variation over Bangladesh: *Mausam* 47,2 pp. 157-162, 1996. Table 2, p.159.

The following Table 2 shows that during El-Niño years, Bangladesh received deficit rainfall or experienced bad monsoon conditions.

Table 2. El Niño Effects on the Monsoon (Debsarma)

Sl. No.	**El-Niño Years**	Monsoon Status
1.	1953	Deficit Rainfall
2.	1957(Severe El Niño)	Deficit Rainfall
3.	1972	Bad Monsoon
4.	1976	Deficit Rainfall
5.	1982 (Severe El Niño)	Bad Monsoon
6.	1987	Bad Monsoon
7.	1997 (Severe)	High temperature and unprecedented and unusual fog for 10 days during the winter of 1998 and also high temperature during the Southwest monsoon of 1998.

Source: Karmakar, Samarendra, "1997-98 El Niño Event with Responses and Plan: Bangladesh Perspective" BMD, Dhaka, (Paper presented at the seminar in BPATC, Savar, Dhaka, Sept. 05, 1999).

The El Niño phenomenon in 1997 led to severe drought in South Asia, and there was a severe shortage of rainfall in Bangladesh. A forecast was made by SPARRSO to the effect that El Niño factors would bring in drought in the country, and when the event became a reality, it strengthened the inference that El Niño was responsible for this unnatural behavior of the climate. A positive correlation has been found between the negative value of the SOI (e.g., El Niño) and drought in Bangladesh. Experts believe in the historical records, which suggest that major famines of the region are connected with El Niño phenomenon. For example, El Niño is believed to be responsible for the famines in this region in the years 1974, 1969 and 1943.

It is also believed that the Great Bengal famine year of 1770, when about one third of the population of Bengal was wiped out, was an El Niño year. Another great famine occurred in Bengal in 1943, which was also an El Niño year. The years 1940-41 were also El Niño years. Perhaps the combined effects of these consecutive bad monsoon years depleted the crop stock to a great extent and coupled with the wartime procurement effects accelerated the onset of the famine of 1943 in undivided Bengal; one-fifth of the population was wiped out. Another famine occurred in independent Bangladesh in 1974. The years 1972-73 were El Niño years, which then continued into 1974, when, again, we experienced the recurrence of a great flood. Perhaps a combination of all these factors depleted the food stocks and led to the famine of 1974. In recent years, of course, large-scale irrigation has been introduced and, because of better food policies, the shortfall of crops appears to have been averted.[38]

Some interesting features have come out regarding the connection between ENSO and floods in Bangladesh. Figure1 indicates the ENSO index. The most catastrophic floods in Bangladesh occurred in 1954, 1955, 1974, 1987 and 1988[39] and also in 1998. The years 1954, 1955, 1988, and 1998 are years with positive SOI indices while 1974 and 1987 are years of continuing El Niño events. The main El Niño occurred in the previous years, and in these years negative anomalies were not that strong. In the major El Niño years, i.e., 1951, 1957, 1972, 1976, 1982, and 1986, we experienced no catastrophic flooding in Bangladesh. Thus we

[38] Choudhury, Dr. A.M: Dependence of Rainfall and Flooding in Bangladesh on ENSO Phenomena, SPARRSO, Dhaka. Paper Presented at the SAARC Seminar on Predictability of Monsoon Rain and Flooding, BMD, Dhaka, 19-21, June, 1996.

[39] Choudhury, A.M. (1989); Flood-1988 as seen by Satellites. Bangladesh Quest. Vol.1, No.1, pp 52-54, Dhaka.

can come up with the hypothesis that during major El Niño years, at least during the first year of El Niño, Bangladesh can be spared from catastrophic floods. The years 1963, 1965 and 1969 were moderate El Niño years, and in those years, we observed moderate floods in Bangladesh. Thus we have concluded that during positive and weak SOI (positive and negative) years Bangladesh can be a victim of flood (Choudhury, 1996).

Fig 1

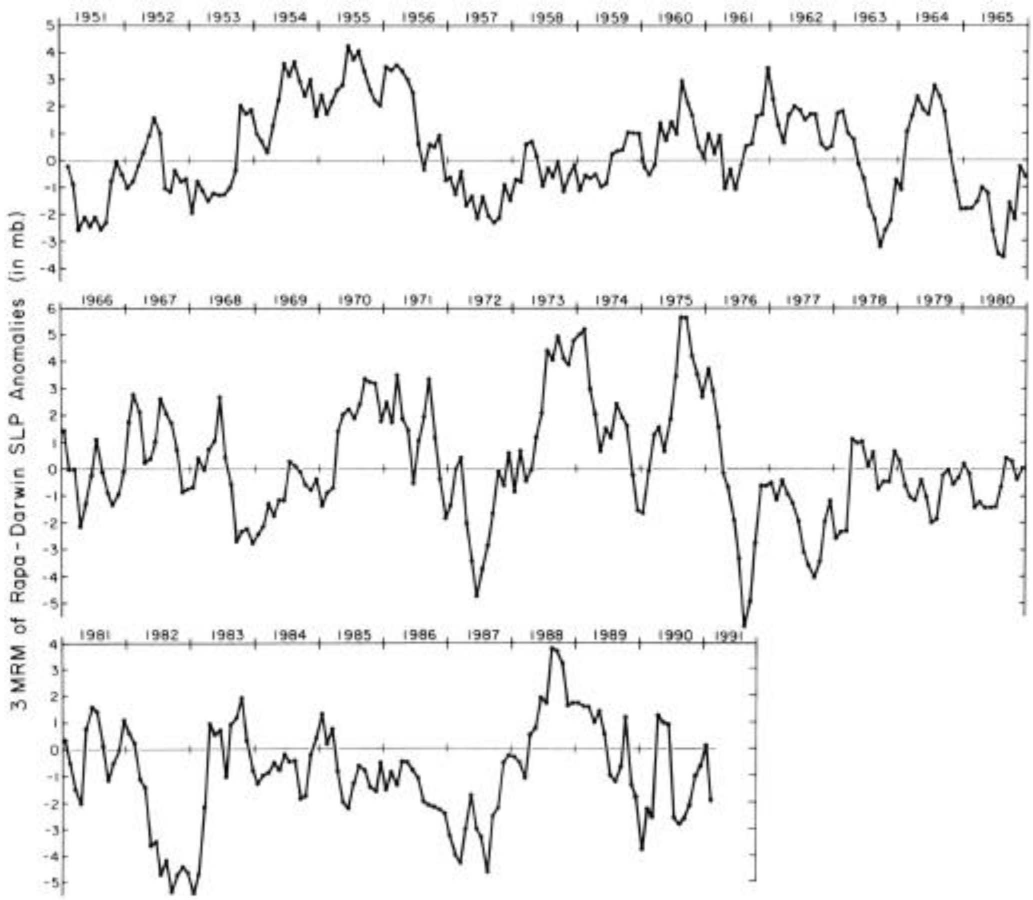

Fig. 1: Three-month running mean plot of anomalies of the difference in sea level atmosphere pressure (mb) Rapa Island (27º37'S, 144º20'W) and Darwin, Australia (12º26'S, 130º52'E). Anomalies are based on data for 1951-1988 [taken from Diaz and Markgraf (1992)].

In this respect, let us look at the oscillation of the longitudinal movement at 28.5°C isotherm along the equator (4°N - 4°S) in the Pacific, shown in Fig 2. We notice that, during the catastrophic flood years in Bangladesh (with the exception of 1987), the 28.5°C isotherm stays west of 165°E longitude. For strong E1 Niño years, this isotherm is located east of 160°W longitude, and these are the years of practically no flood in Bangladesh. If the 28.5°C isotherm stays between these two limits, perhaps floods in Bangladesh will be moderate.[40]

[40] Choudhury, A.M., Bangladesh Floods, Cyclones and ENSO. Proc. of the International Conference on Monsoon Variability and Prediction held at ICTP, Trieste, Italy, 9-13 May 1994, published by WMO, Geneva, 1994.

Fig 2

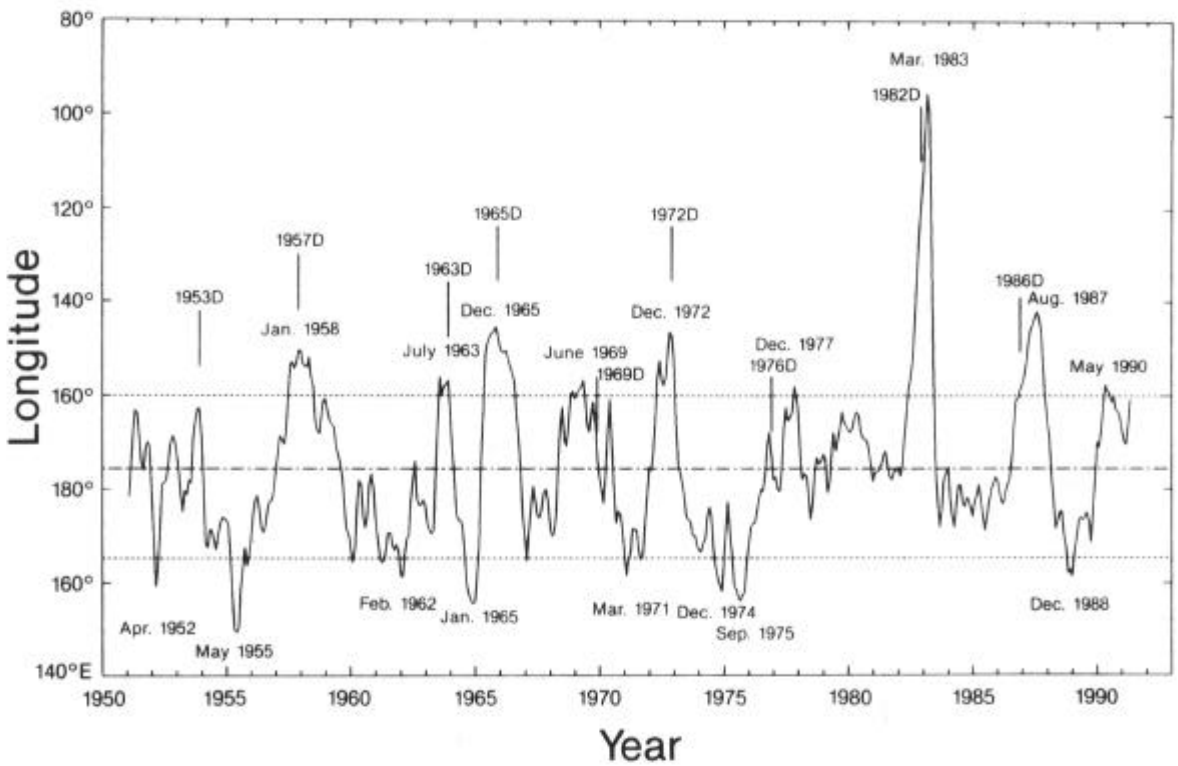

Fig. 2: Time variation of the longitude of the 28.5ºC isotherm along the equator (4ºN- 4ºS) for the period of January 1951-June 1991. Values are 3-month running means [taken from Diaz and Markgraf (1992)].

It is an El Niño condition when the Southern Oscillation Index (SOI) becomes negative, and it is a La Niña condition when the SOI becomes positive. In the case of a high positive SOI, Bangladesh may face severe floods as, for example, in 1988. Moreover, another El Niño situation was observed from March 1997, which continued up to March 1998. Afterward a La Niña emerged, and a devastating flood took place in 1998. This flood was also the longest-lasting flood in duration in Bangladesh. It can be highlighted here that, after the 1972 El Niño year, Bangladesh faced a severe flood in 1974, and after the 1986 El Niño year, Bangladesh suffered from severe floods in both 1987 and 1988; after the 1997 El Niño year, Bangladesh also suffered from severe floods in 1998.[41]

3.1.2 Cyclones in Bangladesh and ENSO

We have observed that during strong El Niño years, Bangladesh has not been struck by any catastrophic cyclone. Table 3 (Choudhury, 1994) gives a list of the major cyclones that struck Bangladesh since 1960. We also noted that, when the ENSO (SOI) index is small (positive or negative) and when the 28.5 °C isotherm stays west of 165 °E longitude, the chance that Bangladesh will be hit by a cyclone is quite high. This explains why, between the years 1960 and 1970, cyclone occurrences in Bangladesh were the highest with eighteen cyclones in

[41] Choudhury, Dr. A.M., "El Niño and La Niña Cycle," SPARRSO, Dhaka, 1997.

eleven years.[42] During this period no strong El-Niño occurred, the ENSO index was moderate, and the 28.5°C isotherm (with the exception of 1965) stayed west of 165°E.

Chances are that a cyclone or a flood will hit Bangladesh if the ENSO index is not strongly negative. Also, the possibility exists that Bangladesh will be spared from a catastrophic cyclone or flood if the ENSO index is strongly negative (i.e., during strong El Niño years) or if the 28.5°C isotherm lies east of 160°W longitude.[43] We know that when the ENSO index is positive (i.e., during cold events), the Walker Circulation is strong, the atmospheric pressure in the Southeastern Pacific is high, and in the Australian region, atmospheric pressure is low and the wind is easterly. But when the ENSO index is negative (during warming when there is an El Niño situation) the Walker Circulation is weakened, and the easterly winds are also weakened or reversed. When the Walker Circulation is weakened, the Hadley Circulation gets stronger, the zonal winds weaken and the meridian winds are strengthened. We believe that the strength of the Bangladesh monsoon is governed by the movement of the tropical disturbances formed in the Pacific. The Bay of Bengal, during the monsoon period, which is the origin of most of the rainfall in Bangladesh and in the catchment area of its rivers, have their origin in most of the depressions or disturbances formed in the Pacific. When the ENSO index is positive and high, the Walker Circulation is strong, the upper tropospheric wind in the Australian region is easterly, and consequently the tropical disturbances are transported westward, which move into the Bay of Bengal and the Bangladesh region. However, if the Walker Circulation is weak, the Hadley Circulation is strong and the upper tropospheric winds in the Pacific are westerly, and, as a consequence, the tropical disturbances formed are transported northward or northeastward, thereby depriving Bangladesh and the region of the rain, causing either below average rain and or drought. It may be due to the position of the 28.5°C isotherm. If the isotherm lies east of the 160°W longitude, tropical disturbances formed in the Pacific do not affect Bangladesh. This is the same reason why during strong El Niño years, Bangladesh is spared from catastrophic cyclones. On the other hand, if the El Niño is weak or moderate, the Hadley circulation may not be very strong and allows some of the tropical disturbances to cross into the Bay of Bengal and enter up to Bangladesh, causing floods and cyclones, as Bangladesh falls between 22-26°N of the Equator.

[42] Choudhury, A.M., Bangladesh Floods, Cyclones and ENSO. Proc. of the International Conference on Monsoon Variability and Prediction held at ICTP, Trieste, Italy, 9-13 May 1994, published by WMO, Geneva, 1994. pp. 6-7.

[43] Choudhury, A.M., Bangladesh Floods, Cyclones and ENSO. Proc. of the International Conference on Monsoon Variability and Prediction held at ICTP, Trieste, Italy, 9-13 May 1994, published by WMO, Geneva, 1994.

Table 3. Cyclones Affecting Bangladesh Since 1960

Date	Deaths	Max. wind speed in (km/hr)	Storms surge height (in ft.)
09 Oct. 1960	3,000	162	10
30 Oct. 1960	5,149	210	15-20
09 May 1961	11,466	146	8-10
30 May 1961	-	146	20-29
28 May 1963	11,520	203	14-17
11 April 1964	196	-	-
11 May 1965	19,279	162	12
31 May 1965	-	-	20-25
14 Dec. 1965	873	210	15-20
01 Oct. 1966	850	146	15-30
11 Oct. 1967	-	-	6-28
24 Oct. 1967	-	-	5-25
10 May 1968	-	-	9-15
17 April 1969	75	-	-
10 Oct. 1969	-	-	8-24
07 May 1970	-	-	10-16
23 Oct. 1970	300	-	-
12 Nov. 1970	500,000	223	20-30
08 May 1971	-	-	8-14
30 Sept. 1971	-	-	8-14
06 Nov. 1971	-	-	8-18
18 Nov. 1973	-	-	8-13
09 Dec. 1973	183	122	5-15
15 Aug. 1974	-	97	5-22
28 Nov. 1974	a few	162	7-16
21 Oct. 1976	-	105	8-16
13 May 1977	-	122	-
10 Dec. 1981	2	97	6
15 Oct. 1983	-	97	-
09 Nov. 1983	-	122	-
03 June 1984	-	89	-
25 May 1985	11,069	154	10-15
29 Nov. 1988	2,000	162	5-10
29 April 1991	138,000	225	20-25
02 June 1991	-	100	6
02 May 1994	170	200	-
19 May 1997	126	225	15
26 Sept. 1997	70	150	10
20 May 1998	3	120	-

Source: Choudhury, A.M., Bangladesh Floods, Cyclones and ENSO. Proc. of the International Conference on Monsoon Variability and Prediction held at ICTP, Trieste, Italy, 9-13 May 1994, published by WMO, Geneva, 1994.

The same mechanism can also be used to describe a “break monsoon,” a phenomenon during which rainfall is absent on the South Asian subcontinent. The figures show both the regions (the Quelccaya Ice Cap in Southern Peru and the Dundee Ice Cap of Tibet) have positively correlated sources of moisture.

Thus we see that in order to understand the monsoon phenomenon, we cannot confine ourselves to the Indian Ocean region alone. The control of the monsoon seems to lie in the Pacific Ocean and it is the Walker Circulation, which largely governs the monsoon variability in Bangladesh (Choudhury, 1994). The above discussions clearly support the existence of El Niño teleconnections to Bangladesh.

3.2 Climate Related Anomalies and Impacts of the 1982-83 El Niño Events

Among the strong and intense El Niño events, the event of 1982-83 El Niño was the strongest before 1997-98. In the previous section, we found that there was a proven El Niño teleconnection in Bangladesh. To analyze the climate-related anomalies and impacts of the 1982-83 El Niño event in Bangladesh, we have considered the common climatic variables such as rainfall, temperature, humidity and sea level pressure. To analyze rainfall anomalies we have selected four meteorological stations on regional basis in Bangladesh: Cox's Bazar, Dhaka, Khulna and Sylhet. Table 4 presents annual rainfall in terms of actual, normal and the anomalies over the four stations in 1981, 1982, 1983 and 1984 to make a comparison among El Niño years (1982-83) and before (1981) and after (1984) El Niño years. In the table the figure in the parentheses “( )” in the first column under the station name shows the normal rainfall of the respective station. 1981, which is a year preceding El Niño, shows a significant amount of excessive rainfall in all four stations. The normal (average) rainfall for the selected four stations in 1981 was 2841 mm but the actual average rainfall was 3125 mm. The anomalies (observed average increase) in rainfall were increased by 9.1% of its normal average. The El Niño year 1982 shows a significant amount of deficit rainfall in all the stations except one (Sylhet). The actual average rainfall was 2432 mm for four stations in 1982, while the normal average rainfall was 2841 mm. The rainfall anomalies stand at a deficit of 409 mm. On average there was a rainfall deficit of 16.8% in the El Niño year of 1982. Moreover, the anomalies in the El Niño 1983 show that there was also a rainfall deficit of 11.4% on average. And, in 1984, the year after an El Niño, there was excessive rainfall by 6.4% on average. The analysis shows that there was very consistent behavior in the rainfall pattern response to that El Niño year. That is, there were rainfall deficits in El Niño years and a surplus (or excessive) rainfall in the preceding and following El Niño years.

Table 4. Annual Rainfall in Selected Four Stations (in mm)

Year / Station	1981		El Niño 1982		El Niño 1983		1984	
	Actual	Dep.	Actual	Dep.	Actual	Dep.	Actual	Dep.
Cox's Bazar (3727)	3803	76	2219	-1508	723	-3004	2787*	-77*
Dhaka (2044)	2177	133	1806	-238	2329**	305**	3226	1182
Khulna (1716)	2281	565	1379	-337	2051***	-600***	212	-1204
Sylhet (3877)	4241	364	4323	445	4846	969	4676	799
Average (2841)	3125	284.5 + (91%)	2432	-409 (-16.8%)	2487	-282.5 (-11.4%)	2725	175 +(6.4%)

Source: Field Visit in BMD, Dhaka. * = 9 months total; ** = 10 months total; *** = 11 months total.

A study conducted by Ahmed, Munim, Begum and Choudhury on "El Niño Southern Oscillation and Rainfall variation over Bangladesh" also found consistent results. Four stations: Jessore, Dhaka, Barisal and Srimangal were selected for their study (Table 5).

Table 5 reveals that there were negative anomalies, that is, a deficit in the rainfall at selected stations in the El Niño year 1982. The average deficit was -212.63 mm in the El Niño year. Moreover, there was excessive rainfall in both the years before (1981) and after the1983 El Niño year. The findings of this study also show consistent behavior with our previous analysis.

Table 5. Mean Rainfall Anomaly (Yearly)

El Niño Year 1 = 1981 Rainfall Anomalies				El Niño Year 1982 Rainfall Anomalies				El Niño Year +1 = 1983 Rainfall Anomalies			
Jessore	Dhaka	Barisal	Srimangal	Jessore	Dhaka	Barisal	Srimangal	Jessore	Dhaka	Barisal	Srimangal
206.46	87.7	184.33	-53.66	-268.5	-272.3	-274	-35.66	126.5	283.7	48.9	601.33
Average 106.21				- 212.63				265.11			

Source: Ahmed, ASM Sabbir, and Munim. A.A., Begum. Q.N., and Choudhury A.M.; El Niño Southern Oscillation and Rainfall Variation over Bangladesh, SPARRSO, Dhaka, July, 1995, from Table 3a and 3b, p.160. Published in Mausam, 1996, 47.2.

Table 6. Annual Temperature in the Four Selected Stations

Year	1981					1982					1983					1984				
Station	Max	Min	Mean	Norm	Dep	Max	Min	Mean	Norm	Dep	Max	Min	Mean	Nor	Dep	Max	Min	Mean	Norm	Dep
Cox's Bazar	30.0	21.4	25.8	25.8	0.0	29.8	21.6	25.7	25.8	-0.1	29.8	22.1	26.0	25.8	0.2	29.8	22.2	26.0	25.8	0.2
Dhaka City	30.4	21.2	25.9	25.8	0.1	30.1	21.2	25.7	25.7	0.0	31.2	23.1	27.2	27.0	0.2	30.6	21.8	26.2	25.8	0.4
Khulna	30.6	21.6	26.1	26.8	-0.7	30.1	21.5	25.8	26.8	-1.0	30.1	21.0	25.5	26.8	-1.3	30.9	20.9	25.9	26.8	-0.9
Sylhet	29.5	20.1	24.9	24.8	0.1	29.4	20.4	25.0	24.8	0.2	29.4	20.2	24.9	24.8	0.1	30.0	19.9	25.0	24.8	0.5

Source: BMD, Dhaka.

Table 7. Annual Relative Humidity (%) in Selected Stations

Year / Station	1981			El Niño1982			El Niño 1983			1984		
	Avg.	Norm	Dep.	Avg.	Norm	Dep.	Avg.	Norm	Dep.	Avg.	Norm	Dep.
Cox's Bazar	79	80	- 1	78	80	- 2	82	80	2	80	80	00
Dhaka City	75	76	- 1	75	76	- 1	78	76	2	75	76	- 1
Khulna	81	79	2	79	79	00	81	79	2	84	79	5
Sylhet	78	78	00	78	78	00	78	78	00	77	78	- 1

Source: BMD, Dhaka.

Table 8. Annual Mean Sea Level Pressure (MBS) in Selected Stations

Year / Station	1981			1982			1983			1984		
	Mean	Norm	Dep	Mean	Norm	Dep	Mean	Norm	Dep	Mean	Norm	Dep.
Cox's Bazar	1008.7	1008.4	0.3	1008.6	1008.4	0.2	1009.2	1008.4	0.8	1011.4	1008.4	3.0
Dhaka City	1007.3	1007.6	-0.3	1008.1	1007.6	0.5	1007.0	1007.6	-0.6	1007.2	1007.6	-0.4
Khulna	1007.8	1008.0	-0.2	1008.1	1008.0	0.1	1009.1	1008.0	1.1	1007.4	1008.0	-0.6
Sylhet	1008.4	1008.1	0.4	1008.5	1008.1	0.5	1009.0	1008.1	0.9	1007.6	1008.1	-0.5

Source: BMD, Dhaka.

The anomalies in terms of temperature, relative humidity and mean sea level pressure in the selected four stations have been presented in Table 6, Table 7, and Table 8, respectively, by two El Niño years, and the years before and after the El Niño years. The tables show that there were no such variations and anomalies in temperature, relative humidity and mean sea level pressure in the El Niño years 1982 and 1983, as well as 1981 and 1984, years before and after El Niño. Moreover, they show that there was no significant impact of the 1982-83 El Niño event on temperature, humidity and mean sea level pressure of four selected stations.

The impact of the 1982-83 El Niño resulted in a drought in Bangladesh, which caused losses in agricultural productivity. Because of the deficiency of rainfall in October 1982, about 0.4 million metric tons of Aman crops were lost in Bangladesh. As a result, the poor and marginal farmer classes were adversely affected. Moreover, it created several subsequent effects on socio-economic areas such as poverty, migration, social unrest, the import of food, pressure on foreign currency reserves, development expenditures and overall economic development prospects.

3.3 Climate-Related Physical and Social Impacts of the 1997-98 El Niño (including agriculture, health, water supply, migration, etc.)

3.3.1 The 1997-98 El Niño Period

According to the WMO statement on the status of the global climate in 1998, the El Niño impacts during the years 1997-98 were the largest in the 20th century. The 1997-98 El Niño event started in March 1997 and continued to influence the climate at least up to March 1998.[44]

The 1997-98 El Niño was one of the strongest on record, developing more quickly and with higher temperature increases than previously recorded. The current episode developed rapidly throughout the central and eastern tropical Pacific Ocean during April and May 1997. During the second half of the year, it became more intense than the major El Niño of 1982-1983, with sea-surface temperature (SST) anomalies across the central and eastern Pacific of 2.5°C above normal. The SSTs exceeded 28°C across the central east-central equatorial Pacific at the beginning of May 1997. The normal cooling of ocean waters, typical of June-October, was notably absent. The warming effect of El Niño was a major factor contributing to the record high global temperature in 1997. The estimated global mean surface temperature for land and marine areas averaged 0.44°C above the 1961-1990 base period mean. The previous warmest year was 1995, with an anomaly of + 0.38°C. By mid-January 1998, the volume of El Niño's warm water pool had decreased by about 40% from its maximum in early November 1997; but its surface area in the Pacific was still about 1.5 times the size of the continental USA. This warm pool had so much energy that its impacts dominated world climate patterns until mid-1998.

During El Niño, the tremendous concentration of excess heat in the eastern tropical Pacific Ocean modifies the atmosphere immediately above it. The effects are carried around the globe by the modified circulation in the atmosphere, resulting in changes in the normal weather pattern in many regions. There is some evidence that Bangladesh and other South Asian countries were affected by the El Niño in 1997-98. During the last two decades, El Niño effects were strongest in 1982-83 and 1997-98.

3.3.2 Physical Impact of the 1997-98 El Niño Event

Choudhury opined that there was a 60% deficit in the rainfall in Bangladesh in June 1997, which was caused by the 1997-98 El Niño. That is because the southeast monsoon wind was delayed by one month. Moreover, we faced a short drought condition until June 1997, due to impact of the El Niño of 1997-98.[45] According to the climate forecasts made by SPARRSO, initial information indicated that at the end of the 1997 rainy season there would be deficit rainfall in the Dhaka, Chittagong, Sylhet, Barisal, Khulna and Rajshahi divisions in

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[44] WMO, WMO Statement on Global Climate, 1998 and *Daily Dinkal*, (6 July 1998); El Niño is over in the Pacific Ocean: El Niño Start.

[45] *Daily Dinkal,* (6 July 1998), El Niño is over in the Pacific Ocean: El Niño Start.

comparison to other years.[46] During the El Niño year Bangladesh had a deficit rainfall and a bad monsoon in 1997. Moreover, there were high temperatures, unprecedented and unusual fog for 10 days during the winter of 1998 and also high temperatures during the southwest monsoon of 1998. (Table 2).

It appears from Table 9 that there was deficit rainfall in 1997 at all four selected stations except Khulna. The deficit rainfall in Cox's Bazar, Dhaka and Sylhet was -5.4%, -20.4% and -6.7%, respectively. For the four stations on an average, the deficit was -6.37%.

Table 9. Annual Rainfall in the Four Selected Stations in the 1997-98 El Niño year
(In mm)

Station \ Year	1997	
	Actual	Departure
Cox's Bazar (3727)	3536	- 191 (-5.4%)
Dhaka (2044)	1698	- 346 (-20.4%)
Khulna (1716)	1816	100 (5.5%)
Sylhet (3877)	3633	- 244 (-6.7%)
Average (2841)	2670.75	- 170.25 (-6.37%)

Source: Field Visit to the Bangladesh Meteorological Department, Dhaka.

3.3.3 Temperature Anomalies

The December 1997 to February 1998 period was dominated by anomalous warmth throughout most of the tropics.[47] The global temperature in 1998 was the warmest since reliable instrument records began 139 years ago. A persistent El Niño in the first half of the year (1998), and the unprecedented warmth of the western and central Indian Ocean contributed to this record warm year. Compared to the climatological normal from the year 1961 to 1990, which was itself, a warm era, the average temperature near the surface of the Earth in 1998 was 0.57°C above the 30 year normal. Parts of every continent experienced mean annual surface temperatures within 10% of the warmest on record. Bangladesh experienced high temperatures, unprecedented and unusual fog for 10 days during the winter of 1998 and also high temperature during the southwest monsoon of 1998 (Table 2, as noted earlier).

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46 Agricultural Information Service, Agricultural Weather Forecasting: Do's by the Farmers, *Ajker Kagoj*, 15 September 1999.

47 WMO, WMO Statement of Global Climate, 1998, p.7.

3.3.4 Sea Level Rise

The rate of global mean sea level rise, based on 100 to 150 years of sea level records, has been 2.1 millimeters per year. During 1998, global mean sea level rose above normal during the El Niño event (principally due to thermal expansion) and then returned to normal.[48]

After the 1997-98 El Niño episode and in the La Niña impact in late 1998, there was an unprecedented long flood in Bangladesh. One of the main causes of this long flood duration was sea level rise in the Bay of Bengal. As a result of a backwater effect, the riverine floodwaters could not pass into the Bay of Bengal from upstream, thereby prolonging the floods.

3.4 Socio-economic Impacts of the 1997-98 El Niño

In our previous discussion about the physical impacts of the 1997-98 El Niño, we found rainfall deficit in all four stations except Khulna (Table 9). On average, the yearly rainfall deficit in 1997 for the four selected stations was 6.37%. It is remarkable that there was a 60% deficit in rainfall in Bangladesh in June 1997 due to El Niño. As a result, Bangladesh faced a short drought in 1997.

The society of Bangladesh is still predominantly agricultural in terms of production and employment, and agriculture is the single largest sector of the Bangladesh economy. Its contribution to the GDP is about 32% (inclusive of crops, fisheries, forests and livestock). The crops sub-sector contributes about 23% (1997-98) to the GDP. In some ways the total agricultural production depends on nature. Relatively speaking, winter crops are less dependent on nature. Rice, however, which is grown in summer and in the rainy seasons, is totally dependent on rain and the natural water reservoirs. Therefore, the impact of deficit rainfall on agriculture was significant in Bangladesh. It ultimately creates an impact on society as a whole and at the individual farmer level as well.

3.4.1 Impact on Agriculture

In 1997-98, Bangladesh experienced deficit rainfall with a subsequent short drought in the main crop production season; a crop loss occurred. In that year, the main crop production declined by 12% to 20% compared to a normal year (Shahabuddin, 1998). According to the farmers, due to deficit rainfall, Aman rice production losses ranging from 25% to 30% is very significant in the context of the Bangladesh economy as well as at the individual farmer level. According to the Bangladesh Economic Review in 1998, production of Aman in 1997-98 suffered because of the lack of adequate rainfall. Production of Aman was 0.7 million metric tons lower than in the previous year.

[48] WMO, WMO Statement on Global Climate, 1998. p.7.

3.4.2 Impact on the Price of Rice

The crop-loss impact was felt in the price of rice in the marketplace. During other years, in the months of December, January and February, the price of rice normally remains low. However, due to the deficit production of Aman rice, the price of rice showed an increasing trend from January 1998. As a result, the government and the Ministry of Food and Agriculture, and other policy makers became very cautious. The government quickly took the initiative to import food in an attempt to cover the deficit. Even then, in the following months food prices were higher than the other years.[49]

3.4.3 Impact on the Growth Rate of Agriculture

The growth rate of agriculture in 1995-96 was 3.7% and was 6.4% in 1996-97. But, due to crop loss resulting from the impacts of El Niño, the agriculture growth rate decreased to 3.1% in 1997-98, or more than 50% less than that of the previous year.[50]

3.4.4 Impact on Inflation

We observed an upward trend in the rate of inflation for the fiscal year 1997-98 (Table 10). The reasons behind this inflationary pressure were mainly due to a new National Pay Scale, a rise in the price of fuel and electricity owing to withdrawal of subsidies and a climate-related decrease in the production of Aman. However, the government tried to control the inflationary situation by importing food grain in the public and private sectors and the open market sales of food grains.[51]

Table 10. Inflation

Year	CPI of Dhaka City Middle Income Group (Base year 1973-74)	CPI National (base year 1985-86)
1995-96	4.1%	6.65%
1996-97	3.9%	2.52%
May 97 - April 98	6.28%	6.63%

Source: Bangladesh Economic Review, 1998, Ministry of Finance, p.3.

3.4.5 Impact on the National Budget

Loss of agricultural production (especially food losses) due to El Niño 1997-98 and the subsequent impacts of La Niña put considerable pressure on 1998-99 national budget.

[49] Rahman, Rushidan Islam, BIDS. 1998.
[50] *Bangladesh Economic Review* 1998, p.2.
[51] *Bangladesh Economic Review* 1998, p.3.

(i) Revenue Received: The main source of government revenue comes from the tax and non-tax sectors. Of the total revenue, 80% comes from taxes. From the total tax revenue, 55% comes from import duty to cover the food losses. The government took the initiative to import food. This had a negative influence on tax collection revenue. Because of emergency food imports, a tax exemption was given to imported food. On the other hand, because of the increase in food imports, the imports of other goods decreased. As a result, tax collection also decreased significantly. The 1998 tax collection year was 10% below its target.

(ii) Expenditure Side: The government had to spend a lot of money to import an additional one million metric tonnes of rice to cover agricultural losses resulting from El Niño's impact. Moreover, to combat the food crisis the government had to take recourse to open market sales (OMS) at reduced prices. All these added expenses created problems in funding the government's normal development expenditures.

3.4.6 Impact on Poverty

In the macro context government could cover losses by reallocating its resources, but problems became acute at the individual level. Most of the people in Bangladesh live below the poverty level. Therefore, the poor and marginal farmers who lost their agricultural production due to El Niño did not have any backup reserve power to cover their losses. By losing their crops, they lost everything and ultimately they were poverty-stricken. Moreover, due to food price increases in the market and inflationary pressure, their purchasing power decreased significantly and they could not afford to buy basic foods. They suffered from malnutrition and diseases. Gradually, they lost their livelihood. Therefore, El Niño's impacts at the micro level became very acute and resulted in social unrest and increased criminal activities in the society.

3.4.7 Impact on Migration

Crop losses forced many marginal farmers to search for other means of livelihood. Having no other alternative in their home areas, they had to migrate to other city areas, especially the capital city where they could find something for their livelihood. In this gradual process, a lot of people became homeless and have ended up living in slums in very pitiable conditions, especially in Dhaka City.

3.4.8 El Niño-La Niña and Flood

After severe El Niño events, Bangladesh experienced severe flooding due to the subsequent La Niña event's impacts. La Niña flood impacts cannot be isolated from El Niño events. After the El Niño situation in 1997-98, La Niña started in May 1998, and Bangladesh faced its most severe, longest flood ever recorded. The impacts of the flood are analyzed below.

3.4.9 Flood Impact on Area and Population

The total flooded area has been divided into three parts based on flood severity: normal flooded area which was flooded over by 50 cm. above the danger level; medium flooded areas with water at 50-100 cm. above the danger level; and severe flooded areas having more than 100 cm above the danger level.

Table 11 shows that out of 64 districts and 460 *Thana*s in the country, floods adversely affected 52 districts and 314 *Thana*s in 1998. Among the *Thana*s, 124 *Thana*s were affected by severe flooding and medium floods affected 125 *Thana*s. In terms of the geographic area of the country, 51% was flooded and approximately 3.1 crore (1 crore = 10 million) people (26% of the total population) were affected by flooding and, as a consequence, about 26 lakh (1 lakh = 100,000) houses were affected.

Table 11. Damage of People and Houses by Severity of Flood, 1998

Flood Situation	Flooded Districts	Flooded *Thana*s	Nos. of Flood affected People (×1000)	Nos. of Flood affected Houses (×1000)
Normal Flooding	11	65	6,704	239.4 (9.0)
Medium Flooding	23	125	8,241	485.6 (18.3)
Severe Flooding	18	124	16,304	1,922.0 (72.7)
Total	52	314	31,249	2,647.0

Source: Chowdhury, Omar Haider and Others; "Loss and Destruction of 1998 Flood and its Impacts on Macro Economics," *Bangladesh Development Studies*, No. 16, Annual No. 1405, BIDS, Dhaka.

3.4.10 Infrastructural Damages

a. Roads and communication: About 7,747 km of highway and 4,855 km of local and municipal roads were damaged in the 1998 flood. Table 12 shows that metalled and nonmetalled roads that cost about Tk.794 (US1$ = 54.35 Taka) and connected bridges and culverts which cost about Tk. 294 million were damaged. Altogether, roads and bridges that were damaged amounted to the loss of Tk. 1087 million. Moreover, railways in the eastern and western regions were also largely damaged. Primary calculations show that about 500 km of railways and 130 connected rail bridges were damaged, requiring Tk. 153 million to rehabilitate.

b. Embankments and Irrigation Systems: Embankment, flood control and drainage systems were also greatly damaged by the 1998 flood. About 1764 km of embankment which was used for roads and about 350 km irrigation canals were also damaged by flooding. About Tk. 313 million were estimated for repair and rehabilitation of the damage.

c. Educational Institutions: The structure, furniture, equipment and books of about 22 thousand educational institutions were damaged in the 1998 flood. About Tk. 273 million was estimated to cover these losses.

d. Climate and Health: Extreme weather events in 1998 caused significant outbreaks of diseases throughout the world. Poverty and disease in society depend on food intake and nutrition conditions. Flood cannot automatically be considered a cause of massive injury and death. At the time when floodwaters went down, the entire drainage system collapsed. As a result, there was an outbreak of infectious diseases, which became life threatening, especially for children. An estimated 1500 people lost their lives in the flood. Moreover, there were outbreaks of diarrhea and hepatitis and other diseases in the flood-affected areas. As a result of the floods, 762 health centers were affected and about Tk. 32.5 million were the estimated losses in this area. District hospitals and health complexes were especially flood damaged. Table 13 shows that about 762 health centers were affected and the loss was amounted to an estimated Tk. 33 million.

e. Damage to Residential Housing: About 2.6 million residential houses were flood damaged, 73% of which were in the severely flooded area.

Table 12. Total flood damage (crore Taka, 1998-99 price)

Sl. No.	Sector	Amount	% of total damaged	% of 1998-99 GDP
1.	**Infrastructure:**			
	a. Roads and Bridge	1087.00	10.63	0.71
	b. Railway	153.00	1.50	0.10
	c. Embankment and Irrigation Canals	313.00	3.06	0.20
	d. Educational Institutions	273.00	2.67	0.02
	e. Health Centers	33.00	0.32	1.36
	f. Housing sector	2090.00	20.43	2.56
	Total	3949.00	38.61	2.56
2.	**Industrial Sector:**			
	a. Large Industries	222.02	2.17	0.14
	b. Small and Medium Industries	904.92	8.85	0.59
	c. Cottage Industries	100.28	0.98	0.06
	Total	1227.22	12.00	0.80
3.	**Agricultural Sector:**			
	a. Crops	4377.00	42.79	2.84
	b. Others	675.00	6.60	0.44
	Total	5052.00	49.39	3.28
	Grand Total	10228.22	100	6.64

Source: Chowdhury, Omar Haider, and Others: "Loss and Destruction of 1998 Flood and its Impacts on Macro Economics," *Bangladesh Development Studies*, No. 16, Annual No. 1405, BIDS, Dhaka.

Table 13. Damage to Health Centers
(000) In 1998-99 prices

Division	Health Centers affected	Damage (x100 taka)
Dhaka	351	146,300
Chittagong	136	65,695
Rajshahi	179	6983.2
Khulna	26	4996
Barisal	12	4650
Sylhet	58	33,670
Total	762	325,143

Source: Chowdhury, Omar Haider, and Others; "Loss and Destruction of 1998 Flood and its Impacts on Macro Economics," *Bangladesh Development Studies*, No. 16, Annual No. 1405, BIDS, Dhaka.

Within the infrastructural sector, damage in the residential housing sector was the highest. The total damage in the residential sector was Tk. 2090 crore (Table 14).

Table 14. Damage to Residential Housing
(x1000) 1998-99 prices

Type of Flooding	Structural Damage	Damage to household goods	Total
Normal Flooding	123,814	-	123814
Medium Flooding	1,518,196	413,079	1,931,275
Severe Flooding	14,042,380	4,804,581	18,846,961
Total	15,684,390	5,217,660	20,902,050

Source: Chowdhury, Omar Haider, and Others; "Loss and Destruction of 1998 Flood and its Impacts on Macro Economics," *Bangladesh Development Studies*, No. 16, Annual No. 1405, BIDS, Dhaka.

Table 15 shows that residential housing suffered from the most damage (52.9%) within the Infrastructural sector. The record largest sub-sector was roads and bridges (27.6%).

Table 15. Statement of Total Damage in the Infrastructural Sector
(X1000) 1998-99 prices (One Crore = $0.5 million)

	Infrastructural Sub-sector						
	Roads and Bridges	Railways	Embankment and Irrigation	Education Institute	Health Center	Residential housing	Total
Damage in crore Tk.	1087	153	313	273	33	2090	3949
%	27.6	3.9	7.9	6.9	0.8	52.9	100.00

Source: Chowdhury, Omar Haider, and Others; "Loss and Destruction of 1998 Flood and its Impacts on Macro Economics," *Bangladesh Development Studies*, No. 16, Annual No. 1405, BIDS, Dhaka.

3.4.11 Loss in the Agricultural Sector

There are four sub-sectors in agriculture: crops, fisheries, livestock and forestry. The contribution to agriculture from these sub-sectors is 73%, 10%, 10% and 7%, respectively. Food crops contribute 75% of value of the crop sub-sectors. Of the total rice production, 50% comes from Aman crops.

In most of the areas, the flood began to hit just after harvesting the Aush crop and even at the time of the Aman plantation, 3.0 lakh ton Aush crops were damaged. On the other hand, the flood remained during the time of Aman cultivation. In a few areas, farmers attempted Aman cultivation three times, but the cultivation was damaged by flood. Considering different studies by government and other organizations and analyzing their findings, it was found that rice production declined by about 2.1 to 2.7 million metric tonnes and 2.2 million tonnes of Aman crops were damaged. In agriculture, crops loss was estimated at Tk. 4377 crore which was 42.79% of total loss and 2.84% of 1998-99 GDP.

Losses in the livestock sub-sector were estimated at about Tk. 675 crore. In the fisheries sub-sector most of the fisheries ponds were flooded and, as a result, escaped from the ponds to open waters. Fish cultivators suffered a great financial loss.

In agriculture, crops and others sub-sectors altogether accounted for losses of about Tk. 5052 crore, or about 50% of the total loss and 3.28% of the 1998-99 GDP (Table 11).

3.4.12 Loss in Industry

The industrial sector was greatly damaged by the 1998 flood. Some export-oriented industries in greater Dhaka as well as medium-sized and small industries all over the country were greatly damaged. According to an estimate of the Bangladesh Chambers of Commerce and Industries, the floods affected about 5000 industrial units. Their production loss was US $425 million. According to the BSCIC, 18% of small industries and 19% of cottage industries were affected. Among the large industries significantly affected by flood, textiles, sugar, the export oriented garments industries, frozen foods, and jute lost much of their production (Table 12).

3.4.13 Total National Flood Loss

The total national flood loss for 1998 is presented on Table 12. The table shows that in terms of money, the total loss was Tk. 10,228.22 crore, or about 7% of 98/99 GDP. Agriculture was the most affected sector, accounting for about 50% of the total loss. The next most affected sector was infrastructure, which was 38.61% of the total loss and 2.56% of 1998-99 GDP.

3.4.14 Food Import

Initially, 1.75 million metric tonnes of food was estimated for import in the budget. Subsequently, after the floods, the estimate was increased to 3.66 million metric tonnes.

Table 16 shows that about four times more food than was budgeted had to be imported by the government. Private commercial imports doubled from their budgeted amount after the flood situation.

It was estimated, that because of the floods, an additional one million metric tonnes of rice would have to be imported by both private and government initiatives. About US $250 million would be required, creating a negative impact on the country's balance of payment. The total imports of rice and wheat on a commercial basis for 1998-99 were estimated at US $290 million.

Table 16. Food Import from Institutional Sources
(x1000 metric tons)

	Budgeted			After flood		
	Rice	Wheat	Total	Rice	Wheat	Total
Food from Foreign Aid	0.0	600.0	600.0	26.0	1102.0	1128.0
Government Import by Commercial basis	159.0	200.0	250.0	606.0	425.0	1031.0
Private Import by Commercial basis	600.0	200.0	800.0	1200.0	300.0	1500.0
Total Import	750.0	1000.0	1750.0	1832.0	1827.0	3659.0

Source: Chowdhury, Omar Haider, and Others; "Loss and Destruction of 1998 Flood and its Impacts on Macro Economics," *Bangladesh Development Studies*, No. 16, Annual No. 1405, BIDS, Dhaka.

Moreover, probable losses in different projects under the Annual Development Program (ADP) funded by the government and by foreign sources was estimated to be around Tk. 4300 and Tk. 1200 crore, respectively. The government was trying to keep its annual development program unchanged, by making budget cuts in other sectors. Above all, it was estimated that there would be Tk.1000 crore less expenditure in its ADP from its targeted expenditure.

We have noted that the total food deficit came to 4.38 million metric tonnes because of the flooding. The government also took proper initiatives for facing this deficit by imports and from foreign aid sources. Therefore, in a macro context, there was no food problem; but problems were at the individual level, which depended mainly on the purchasing power of individuals. The government had taken a very bold step to face this challenge. Under a Vulnerable Group Feeding Program (VGFP), the government gave food directly through its own and local government machinery to five million vulnerable people for 3-4 months in the crisis period that followed the flood. As a result, problems were addressed efficiently.

3.4.15 Impact on Economic Growth Rate

During the decade of the 1990s, the growth rate was about 4.7%. At the end of the decade the growth rate had become 5.5%. In 1998-99, there was a possibility of a GDP growth rate of 6%. But, due to flood, the losses only in the agricultural and industrial sectors resulted in a decrease in GDP by Tk. 3080 crore. Considering the loss from related effects, these losses might have increased to Tk. 11018 crore in GDP. Therefore, total GDP might have decreased in the range of Tk. 3080 to Tk. 7049 crore, or a GDP growth rate of 1.4% to 4%, respectively. However, because of the proper and timely responses by the government and other agencies, the GDP growth rate was 5.2% in 1998-99. This would have been much higher had there been no flood.

During this flood response operation, the government's ability to respond quickly to calamities and to create employment and provide and distribute food aid demonstrated its ability to face the flood's challenges efficiently.[52]

3.5 RELIABILITY OF THOSE ATTRIBUTIONS

The societal impacts in Bangladesh in 1997-98 are consistent with the expected impacts of El Niño and La Niña, which prove reliability of those attributions.

3.6 RESPONSES

3.6.1 Government Reports or Statements Appearing Before the Impacts of the 1997-98 El Niño.

The issuance of a government report or statement before the occurrence of a hazardous event depends mainly on the prediction of the occurrence of that event. During the last three decades there had been a great deal of investment in monitoring and research to enhance the capacity to predict El Niño. A perfect forecast of El Niño occurrence was not available in October 1996. The WMO, however, reported that by late 1996, La Niña conditions would peak, and climate forecasters were already turning their attention to the possibility of a new El Niño forming in 1997. Early in 1997, most numerical models and empirical forecast schemes had started to indicate the inception and development of a possible major El Niño episode. The forecast came into reality when strong El Niño conditions influenced the climate from March 1997 to May 1998. Moreover, this El Niño condition abruptly turned into a La Niña event after May 1998.

Evidence shows that there was only one statement or report issued by the government, before the impacts of the 1997-98 El Niño appeared. The statement was issued by the Agricultural Information Service with the title "Agricultural Weather Forecast: Action suggested for the Farmers," and appeared in the *Daily Ajker Kagoj* on 15 September 1997. The report highlighted that according to the weather forecast made by SPARRSO, information indicated that there would be deficit rainfall in Dhaka, Chittagong, Sylhet, Barisal, Khulna and Rajshahi divisions in the year compared to other years at the end of the rainy season. The report specifically stated the following:

[52] Chowdhury, Omar Haider, and Others: "Loss and Destruction of 1998 Flood and its Impacts on Macro Economics," *Bangladesh Development Studies*, No. 16, Annual No. 1405, BIDS, Dhaka.

- Due to deficit rainfall in the month of Kartic (October-November) there may be lack of moisture in the soil of transplanted Aman rice fields. In that situation, to get maximum output the farmers are requested to arrange for supplementary irrigation to the field.

- Farmers are also requested to make ready their deep/shallow tube wells, power pump/tradel pump/leg-operated cylinder pumps and to use necessary irrigation.

- They are also advised that if there was lack of rainfall from normal at the end of Vadra (August-September) and in the month of Ashwin (September-October), then they should cultivate vegetables in advance.

- To know more about crop cultivation they are requested to consult with the nearest block supervisors/*Thana* agricultural officer.

There were a few other statements and opinions made by appropriate government officials in different forums that were published in different daily newspapers, but these were not formal government statements or reports. These were the following:

(a) Mr. Ershad Hossain, Director, Bangladesh Meteorological Department said a monsoon in association with a low pressure was persisting over the Brahmaputra and the Ganges basins of Bangladesh indicating the chances of more rainfall.[53]

(b) Dr. A.M. Choudhury, a senior scientist with SPARRSO, said the monsoon that extended from the Bay of Bengal was feeding a low-pressure system that persisted near the Himalayas with clouds causing rainfall. He also said that they should be cautious about the behavior of the rivers, because two full monsoon months were still lying ahead, and the weather pattern continued to remain erratic.[54]

(c) Moreover, Dr. A.M. Choudhury said in his speech on the Impact of El Niño in Bangladesh that El Niño impacts started in Bangladesh from May 1998. As a consequence, was a probability that Bangladesh was going to face heavy rainfall and cyclones with tidal bore from July 1998. He further suggested necessary preparations and the conduct of agricultural weather-related research to face the situation.[55]

[53] *Daily Independent*, Dated: 19 July 1998.
[54] *Daily Independent*, Dated: 19 July 1998.
[55] *Daily Dinkal* (Dated 6 July 1998), El Niño is over in the Pacific Ocean: El Niño Start.

3.6.2 Statements Issued After the Impact

A detailed report/statement prepared by the Government of Bangladesh was used on the World Wide Web. It reported on damages, losses, requirements of goods and services for relief and rehabilitation, due to the flood in 1998, as La Niña impacts arrived just after the El Niño of 1997-1998.

3.6.3 Major Responses to the Event

In the severe and longest flood in Bangladesh in 1998, the government's responses were very positive during the 1997-98 El Niño and the 1998-2000 La Niña. The responses were as follows:

a) Broadcast of advance warnings and a continuous monitoring of the situation.

b) Creation of a national level control and monitoring cell for the flood emergency, relief and rehabilitation programs in the Prime Minister's Office.

c) Initiation of a government food grains procurement process and the taking of requisite measures for the welfare of the people.

d) Emphasis on the procurement of medical equipment, medicines, preparation of oral saline, fresh drinking water and treatment facilities for the flood victims.

As a result, a great calamity was averted.[56]

Moreover, the government monitored the situation very closely and tried to face the situation using its own efforts and resources. When necessary, the government also requested help from the international community.

Further, the Ministry of Disaster and Relief issued orders to the concerned ministries and organizations to take the necessary actions. A government circular was issued from the Honorable Prime Minister's Office to the effect that attendance in disaster management meetings was compulsory for the concerned members. (Md. Shamsuddin Habib, 30 SSC).

[56] Chowdhury, Dr. A.M., "Climate Related Disasters in Bangladesh with Special Reference to El Niño; SPARRSO, Dhaka, (Paper Presented at the Seminar in BPATC, 5 September 1999). Topic 4a

3.6.4 Identification (with citations, if possible) of the Extent of National Research (in the last 20 years) on El Niño and Climate-related Hazards

In Bangladesh the status of national research on El Niño and climate-related hazards is not satisfactory. It is still at a very preliminary position. The research works that were found on the topic were mainly conducted as a result of personal interest and individual initiatives. Interest by the Government of Bangladesh in El Niño rose after a report was published in April 1998 in the newspaper *The Daily Independent*, which included an article about the possible impacts of El Niño upon crop production. Then, the Secretary of the Ministry of Agriculture called a meeting in the Ministry and a presentation on El Niño was made (Minutes of the Meeting held under the Chairmanship of Dr. A.M.M. Shawkat Ali, Secretary, M/o. Agriculture on 3 May 1998). As a result, a research project was given to SPARRSO in collaboration with BARC on the "Development of Models for Predicting Long Term Climate Variability and Consequent Crop Production as Effected by El Niño -La Niña Phenomena," in January 1999. This research contract is still going on.[57]

Dr. AM. Chowdhury conducted research work in 1994 on El Niño at the International Center for Theoretical Physics (ICTP) for the International Conference on Bangladesh Floods, Cyclones and ENSO (Proceedings of the International Conference on Monsoon Variability and Prediction. ICTP, Truest, Italy, 9-13 May 1994, Published by WMO, Geneva, 1994).

Other research work has been done in collaboration with various universities in Bangladesh as noted below:

A.S.M.S. Ahmad, A.A. Munin, Q.N. Begum and A.M. Choudhury, "El Niño Southern Oscillation and Rainfall Variation over Bangladesh": *Mausam* 47,2 pp. 157-162. (7, A.M. Choudhury, p.5). Several seminars and conferences were also arranged in this regard. Day by day, the issue is gaining in importance. Worldwide observations of different meteorological parameters, including observations of conditions in the tropical Pacific, are essential for scientific research and for the study of El Niño.

3.6.5 National Plans to Respond to Disasters

Disaster in Bangladesh is a common phenomenon every year. The people of Bangladesh have withstood disasters with a very courageous spirit. It has become part of their lives, and they have learned to live with natural disaster. To reduce the negative impact of climate-related natural hazards and disasters and to reduce the loss of life and property, a well-planned disaster management mechanism has been set up by the Government of Bangladesh along with the technological enhancement of the forecasting centers.

Various institutional arrangements and mechanisms are now operating at different levels for proper management of disasters in Bangladesh, including the following:

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[57] Chowdhury, Dr. A.M., "Climate Related Disasters in Bangladesh with Special Reference to El Niño; SPARRSO, Dhaka, (Paper Presented at the Seminar in BPATC, 5 September 1999). Topic 4a.

3.6.5.1 At the National Level

- National Disaster Management Council (NDMC), headed by the Prime Minister.

- Inter-Ministerial Disaster Management Coordination Committee (IMDMCC) headed by the Minister in charge o the Ministry of Disaster Management and Relief (MDMR).

- Cyclone Preparedness Program Implementation Board (CPPIB), headed by the Secretary, Ministry of Disaster Management and Relief.

- Disaster Management Training and Public Awareness Building Task Force (DMTTF), headed by the Director General of DMB.

- Focal point Operation Coordination Group on Disaster Management (FPCG), also headed by the director general of the Disaster management Bureau (DMB).

- NGO Coordination Committee on Disaster Management (NGOCC), headed by the Director General of DMB.

- Committee for Speed Dissemination of Disaster Related Warnings/Signal (CSDDWS), headed by the Director General of DMB.

3.6.5.2 At the Field Level

- District Disaster Management Committee (DDMC), headed by the Deputy Commissioner (DC) to coordinate and review the disaster-related activities at the district level.

- *Thana* Disaster Management Committee (TDMC), headed by the *Thana* Nirbahi Officer (TNO) to coordinate and review disaster-related activities at the *Thana* level.

- Union Disaster Management Committee (UDMC), headed by the Chairman of the Union Parishad to coordinate and review disaster-related activities at the Union Level.

3.6.5.3 Emergency Preparedness

With the devastating floods in the late 1980s and the killer cyclone in 1991, the concept of overall disaster preparedness in the country became clear through discussions on a variety of complex and inter-sectoral issues. These issues cropped up in the course of implementation of a short-term project called "Assistance to the Ministry of Relief in the Coordination of Cyclone Rehabilitation." Consequently, the Government of Bangladesh has taken a number of significant steps in the last few years to build up institutional arrangements from the national to the union levels for effective and systematic disaster preparedness in Bangladesh. The steps are as follows:

- Establishment of a disaster management Organization named the Disaster Management Bureau (DMB) in 1993.

- Naming of the Ministry of Relief and Rehabilitation as the Ministry of Disaster Management and Relief (MDMR).

- Establishment of a council and committees at the national, district, *Thana* and union levels for overall disaster management.

3.6.5.4 Disaster Preparedness and Management Manual

To maintain proper coordination among the concerned Ministries, governmental organizations and line agencies, and also to ensure their proper functioning during an emergency, the government has formulated a well setout methodology. To ensure the utility of the methodology, a guidebook, *Standing Orders on Disaster*, was designed as a basic tool. The Standing Orders outlines the activities of each ministry, major agency and department in order to handle emergency situations efficiently. In the effort to make the mechanisms effective and clear, a "Comprehensive National Policy on Disaster Management and National Disaster Management Plan" has been designed in draft form for consideration of the government.

The entire disaster preparedness methodology meets the requirements of clear policies: to provide scope for the implementation of NDMC policies and decisions by the high-level IMDMCC on an inter-ministerial basis; to incorporate the role of the MDMR as the responsible line Ministry; and to provide for the integration of the Armed Forces and to review the crucial roles of the DDCs, TDMCs and UDMCs. The action plans for the DDMCs, TDMCs and UDMCs are under preparation to make these local-based Disaster Management Committees able to prepare the people at the grass-root level and to increase their capacities to cope with disasters.

3.6.5.5 Plans for Strengthening Relevant Forecasting and Warning Institutions

3.6.5.5.1 Disaster Forecasting, Early Warning and Simulation

Two national organizations, namely the Bangladesh Meteorological Department (BMD) and the Bangladesh Water Development Board (BWDB) are responsible for disaster forecasting and early warning services (Islam and Chowdhury, 1999). While BMD is responsible for meteorological observations, preparation of weather charts and issuance of forecasts for disastrous weather systems such as cyclones, etc., the BWDB has the responsibility for overall water management in the country including flood forecasting. Both organizations have a long tradition of service to the community with technical knowledge and skills that developed during the past several decades.

3.6.5.5.2 Meteorological Forecasting and Warning System

Traditional methods of disaster weather forecasting are in existence (in Bangladesh) in which various weather charts such as synoptic surface and upper air charts, constant pressure charts, isobaric charts, and prognostic charts are analyzed manually on a routine basis to extract information about the tendency of hazardous weather systems including cyclones, Nor'westers, the southwest monsoons, etc. For prediction and issuance of early warning while making forecasts and early warnings, the forecasters also use (a) Climatological charts, (b) radar echoes, (c) satellite images and (d) computer information. In fact, old methods of weather forecasting are being gradually replaced by more advanced and sophisticated systems and techniques developed around the weather satellite, radar, computer, etc. These are applied particularly for track prediction of tropical cyclones in the Bay of Bengal. Forecasters at the BMD, along with these facilities available to them, also use a good number of other techniques, such as (i) persistence technique, (ii) Climatological technique (iii) statistical technique and (iv) satellite technique. In the whole process of forecast and warning preparation, the BMD has a modern meteorological communication facility known as the National Meteorological Communication Center (NMCC), which is linked up with a Global Telecommunication System (GTS) through a line capacity of 2400bps. However, it has not yet been possible to go for computer simulations of cyclones, etc., in Bangladesh.

3.6.5.5.3 Flood Forecasting and Warning Operations

The system of flood forecasting and warning operations has been modernized and made operational. The Flood Forecasting and Warning Center (FFWC) under the BWDB was established in 1972 under a project named "Expansion of Flood Forecasting and Warning Services" (with the Danish Hydraulic Institute [DHI] as the main consultant). Under the project, the MIKE 11 flood forecasting model (Super Model) has been constructed to cover the entire northern half of Bangladesh, an area of 82,000 square kilometers with 7,270 km of rivers and flood plains. The preparation of flood forecasts and the issuance of flood warnings by the FFWC follows a sequence of operations:

i. Data transmission and reception;
ii. Satellite image reception and processing; flood forecasting;
iii. Preparation and issue of flood warnings.

The procedure is computer-based and has been highly automated, ensuring the correct execution of each operation. This allows more time to the key players to concentrate on the components that still require their judgment and experience in decision-making.

3.6.5.6 Major Accomplishments in Disaster Forecasting

The government has given priority to improving the warning-issuing capacity of the concerned governmental organizations such as the Storm Warning Centre (SWC) of Bangladesh Meteorological Department (BMD) and the Flood Forecasting and Warning Centre (FFWC) of Bangladesh Water Development Board (BWDB). As a result:

- Microwave links between the SWC in Dhaka to the Radar Stations at Cox's Bazar and Khepupara have already been established to improve the early warning system in case of cyclones.

- With a grant from the Government of Japan (GOJ), replacement of the radar at Agargaon, Dhaka, establishment of a new radar at Rangpur and a satellite ground receiving station at SWC Dhaka were in the process of implementation & will be completed by the last quarter of 1999.

- There has been substantial progress in the expansion of flood forecasting and warning services (FAP-10) in the country under a project with the Danish Hydraulic Institute (DHI) as the main consultant. The project was completed in December 1998.

3.6.5.7 Disaster Mitigation: Theory and Practice

Previously, disaster mitigation tended to be viewed in Bangladesh in terms of structural mitigation measures. This concept has changed over the past few years. The GOB, at present, gives equal importance to both structural and non-structural mitigation measures. It is rather strongly believed by the GOB that non-structural mitigation measures need to be complemented by structural mitigation measures in order to modify or reduce some disaster effects.

3.6.5.7.1 Structural Mitigation

As a part of the structural mitigation measures, the GOB using its own as well as external resources has so far constructed 1,841 cyclone shelters and 200 shelters for evacuation of people from cyclone-and flood-prone situations in response to disaster warnings. In addition, a coastal embankment about 3931 km long and 4774 km of drainage channels have been constructed to protect coastal land from inundation by tidal waves and storm surges.

3.6.5.7.2 Non-structural Mitigation

For non-structural mitigation the GOB has given emphasis to the following:

- Legislation
- Training and public awareness
- Institution building
- Warning systems
- The Disaster Management Legislation (Act) has already been drafted. The Act will provide for the formulation of disaster management policy and planning relating to preparedness and emergency measures and rehabilitation programs to deal with disasters.

- Training and public awareness are important components of the project "Support to Comprehensive Disaster Management." Until December 1998 a total of 183 courses/workshops/seminars have been conducted under this project by the Disaster

Management Bureau, a specialized organization under the Ministry of Disaster Management and Relief. About 10,099 participants attended the program. They included government and semi-government officials at different levels, public representatives, NGO officials, local leaders, representatives from the mass media, teachers, Imams of the mosques, and members of the fishing community.

- Besides, the DMB has supported holding disaster management training workshops in other institutes as well. As part of the public awareness, booklets have been regularly printed and distributed to the grassroots levels containing public information about cyclones, floods, a calendar, and posters depicting disaster points.

- To raise awareness among the students on various aspects of hazards/disaster management, a chapter on disaster management has been included this year in the educational curricula from class V to XII in response to government policy. The GOB also decided to make compulsory a session of at least 2 hours on disaster management in the training curricula of all types of Training Institutes to train officials and non-officials.

3.6.6 Identification (with citations, if possible) of International Research about the Impacts of El Niño Events

According to the experts of SPARRSO and the BMD, no international research work has been conducted on impact of El Niño events in Bangladesh until today. As we have very limited resources in terms of financial and technical expertise as well as modern institutional arrangements, relevant international organizations may come forward to assist Bangladesh in undertaking various ENSO-related research and study programs.

3.6.7 Whether El Niño Can Explicitly be Considered to be a Disaster in Bangladesh

From Table 25 and earlier discussions about historical data related to El Niño-La Niña events and disasters occurring in Bangladesh in the form of drought, flood and cyclone, a relationship was found between El Niño with drought and La Niña with flood and cyclone. A cause and effect relationship was found between El Niño and disasters in Bangladesh. In the case of El Niño events in history, it clearly appeared as a cause of disasters. However, there are other causes of disasters in Bangladesh. Thus, El Niño can be considered explicitly as one of the important causes of disasters in Bangladesh, and therefore the country needs to monitor the development of El Niño carefully.

As there are so many variables to consider in the study of climatic behavior, and as there are very complex interactions among the variables in the atmosphere, the impact of El Niño-related disasters in Bangladesh may help to identify a clearer picture with the advancement of the existing knowledge, skills, science and institutional capacity building.

4.0 Forecasting by Analogy

The purpose of this section is to discuss the "forecasting by analogy" of disaster-related organizations in Bangladesh, considering the points highlighted in the previous sections. This section has three major parts. The first part describes the introduction and functional activities of the concerned organizations using recent historical examples in order to plan ahead. The second part of this section addresses the nature of studies and investigations undertaken by scientists in the concerned agencies on El Niño and La Niña events and examines the analogy of forecasting made by them. In examining the forecasting by analogy of El Niño's impacts, an attempt has been made to discuss the events both in Bangladesh and in an international context. The last part outlines the country's potential role in monitoring and forecasting El Niño events that could be utilized in the national disaster plan. Finally, an attempt has been made to provide some policy options on the impacts of El Niño that would presumably help the government and NGOs to formulate appropriate policy and programs in the future.

4.1 Forecasting Organizations

Bangladesh is one of the major disaster-prone countries in the world; so much so that sometimes experts call it the *landing ground* of disasters.[58] Almost every year the country has experienced various types of natural disasters causing human casualties, economic and social loss, and damage to the environment, thereby creating new demands on the society for reconstruction and rehabilitation. Considering this vulnerability, the Government of Bangladesh established a number of organizations for providing the necessary information on various types of disasters in order to formulate appropriate policy and plan for the future. These organizations are as follows:

Bangladesh Space Research and Remote Sensing Organization (SPARRSO)
Bangladesh Meteorological Department (BMD)
Bangladesh Water Development Board (BWDB)

[58] A.M. Choudhury, "Detection of Cyclone." Paper presented in Seminar organized by Ministry of Disaster Management and Relief, Disaster Management Bureau, March 1999, p.6

Since their establishment, these organizations have continuously generated meteorological and disaster-related information based on their technology and research. Their information is sent to concerned agencies via television, radio and newspapers to forecast and monitor as well as for taking appropriate steps to face the anticipated calamities.

4.1.1 Bangladesh Space Research and Remote Sensing Organization (SPARRSO)

The Bangladesh Space Research and Remote Sensing Organization (SPARRSO) is a multi-sectoral research and development agency of the Government of the People's Republic of Bangladesh. It is functioning as an autonomous organization and is engaged in undertaking research on space science and remote sensing technology.[59]

The application of space technology in Bangladesh began as early as 1968, through the establishment of an Automatic Picture Transmission (APT) ground station on the premises of the Atomic Energy Centre (in Dhaka) for receiving real-time weather pictures directly from meteorological satellites. Subsequently, the Space and Atmospheric Research Centre (SARC) was created in the Bangladesh Atomic Energy Commission in 1972 and the APT ground station was absorbed within SARC. With the advent of the Earth Resource Technology Satellite (ERTS), it was renamed as the Bangladesh Landsat Programme (BLP) in 1977. Finally, the Bangladesh Space Research and Remote Sensing Organization (SPARRSO) was established by an executive order of the President in 1980 by merging SARC and BLP.[60]

4.1.1.1 Objectives

SPARRSO is functioning with the following major objectives:

- To apply space and remote sensing technology to surveying the natural resources and monitoring of the environment and natural hazards in the country.
- To establish a broad-based space and remote sensing data acquisition, processing and dissemination system in the country.
- To operate and maintain satellite ground receiving stations including data collection platforms and develop instrumentation facilities and manpower capabilities for both visual and computer analysis of satellite and airborne data for their application in various sectors of national economy.
- To act as the focal point for space and remote sensing activities in the country and to provide the government with relevant information in formulating national, regional

[59] SPARRSO Annual Report, June 1995.p.1

[60] ibid. p. 7

and international policy on issues concerning space science and remote sensing technology and their application towards a sustainable development.

- To establish regional and international cooperation and collaboration in the peaceful uses of space science and technology.[61]

4.1.1.2 Activities

SPARRSO is engaged in research and development activities in environmental monitoring and natural resources management. In pursuance of these activities, SPARRSO has been applying its technology in different fields, such as oceanography, meteorology, environment, climate change, natural disasters, geology, water resources, agriculture, forestry and fisheries, etc.[62]

Studies like weather monitoring, thematic mapping, monitoring of river-course changes, monitoring of droughts, floods and weather hazards, inventory of forests, land-use analysis, vegetation index mapping, crop monitoring, coastal zone monitoring and change detection, geologic mapping, sea surface temperature mapping, surface circulation dynamics, and so forth, are being done on a regular basis. In addition, SPARRSO undertakes user-specific work in association with the user agencies, organizations and universities. Some of the major activities of SPARRSO are given in the following paragraphs:

(a) Weather Monitoring

In order to monitor and forecast the prevailing weather conditions over Bangladesh, SPARRSO regularly receives NOAA and GMS satellite data both in analogue and digital form through its Advanced Meteorological Satellite Ground Station (AMSGS). These data are processed and analyzed for research purposes and also disseminated to different ministries and relevant organizations like the Bangladesh Meteorological Department (BMD), the Bangladesh Water Development Board, the Bangladesh Agricultural Research Council, the Ministry of Defense, the Ministry of Disaster Management and Relief, etc. The results of interpretation of these data are also provided to relevant departments, if there are any impending events, like cyclones and floods, for facilitating early disaster warnings. The major disasters hitting the country, like the catastrophic cyclones of 1970, 1985, 1991 and 1994 and the devastating floods of 1984, 1987 and 1988, were all monitored by SPARRSO. The early information during cyclonic disasters and floods help much toward saving lives and the properties of millions in the coastal areas of Bangladesh.[63]

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[61] ibid. p.11

[62] ibid. p. 18

[63] SPARRSO, Annual Report, 1997, p. 5

(b) Flood Monitoring

In addition to early warning, digital techniques for flood monitoring and flood-area mapping using satellite data are also being developed at SPARRSO. The floods of 1987 and 1988 were monitored at SPARRSO using real-time NOAA-AVHRR data. The processed images of floods were distributed to various government departments and other organizations for taking precautionary measures. The systematic analysis of cloud pictures for 1988 flood showed that this unprecedented flood occurred because of heavy rainfall in the upper catchment areas of the Ganges and Brahmaputra rivers in the Himalayan region (outside Bangladesh) for over ten continuous days.[64] SPARRSO's achievement in providing early information of impending disasters toward the alleviation of human suffering and the mitigation of losses was highly lauded both within and outside Bangladesh.[65]

A pilot study was made in collaboration with the Chinese Academy of Sciences on a program for Technical Cooperation among Development Countries (TCDC) with the support from the ESCAP for flood-plain mapping and flood monitoring using remote sensing techniques and GIS for a selected site. A digital terrain model (DTM) was also created for the region. The DTM has been used to simulate flood inundation using a hydrodynamic model.[66]

(c) Coastal Zone Monitoring

NOAA satellite imagery has been used to map and monitor the sea surface temperatures (SSTs) of the Bay of Bengal. The surface water circulation, including the complicated system of small and large scale eddies, has been observed in the SST imagery. The imagery has also shown the existence of a well-defined gigantic system of warm western boundary current flowing to the north along the western Bay of Bengal. The distribution of the SSTs and the position of the eddies and the thermal fronts at certain intervals are important for investigations of the biological growth potentials of the Bay and also for understanding the oceanographic dynamics of the coastal zone and deep-sea areas. In order to study the ocean-atmosphere interactions, properties and the surface circulation of the Bay of Bengal, a number of offshore floating buoys were placed on the Bay of Bengal. The buoys provided interesting data during the period of their functioning.[67]

(d) River Course Monitoring

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64 SPARRSO, Newsletters Issue 4 June, 1995, p. 4

65 ibid.

66 ibid.

67 ibid. p. 7

Monitoring of the courses of the major rivers of the country has been done by SPARRSO in different phases. The updated courses of the rivers have been mapped after analyzing satellite and aerial photographic data both visually and digitally. The erosion and accretions have been mapped all along the courses of the major rivers of the country. A drainage-pattern map of the entire country has also been prepared from satellite data.[68]

(e) Climate Change

SPARRSO has carried out a number of studies relating to global warming and sea level rise due to the greenhouse effect. Such studies include trend analysis of temperature, rainfall, etc. in Bangladesh and the possible impacts of climatic change on the country.

4.1.2 Bangladesh Meteorological Department (BMD)

The Bangladesh Meteorological Department (BMD) is an attached operational scientific organization under the administrative control of the Ministry of Defence of the Government of the People's Republic of Bangladesh. The main responsibility of the Department is to record meteorological observations and issue weather forecasts and storm warnings for the general public, aviation and shipping.

To perform these routine tasks, the BMD maintains a network of 35 Synoptic Surface Observatories, 11 Pilot Balloon Observatories, 14 Agro-meteorological Observatories, 3 Radar Stations, 3 Rawinsonde Observatories and one Automatic Picture Transmission (APT) ground receiving station. In addition, the Department has two Main Meteorological Offices (MMO), two Dependent Meteorological Offices (DMO) and three Supplementary Meteorological Offices (SMO) which function around the clock under the direct administrative and technical control of the two Regional Meteorological Centres (RMC), namely the Meteorological and Geophysical Centre (MGC) in the Chittagong and the Storm Warning Centre (SWC) in Dhaka. Meteorological Headquarters at Dhaka overviews the performances of the field offices and renders technical as well as administrative guidance to the two RMCs.[69]

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68 Ali A. and Choudhury, J.U.: "Tropical Cyclone Risk Assessment with special reference to Bangladesh." *Mausam*, India, 1996, p. 31

69 Bangladesh Meteorological Department, The Project for Establishment of Micro Link, July 1992, p.9.

4.1.2.1 Major Activities

All these stations and observatories are equipped with both conventional and sophisticated instruments. With the help of these observatories, the BMD observes and records all meteorological parameters at synoptic hours (06, 09, and 12 BST) throughout the country. The special function of the Bangladesh Meteorological Department is to render technical advice on meteorology to all the concerned ministries of the government as and when required.

(a) Radar Stations

To monitor continuously the development, movement and intensity of tropical cyclones in the Bay of Bengal, the Bangladesh Meteorological Department has been maintaining two weather surveillance radars at Cox's Bazar and Khepupara for about two decades. There is also another radar station at the top of the Headquarters building in Dhaka.

At Cox's Bazar the weather surveillance radar station was established in 1969 under the sponsorship of the Swedish Save the Children Federation, with an S-band Mitsubishi RC-32A weather radar having a detection range of 400 kilometers.[70] This radar worked satisfactorily for more than a decade and a half and was very helpful in detecting a number of cyclones including the killer cyclone of November 1970. The radar became obsolete with deterioration of its performance and was replaced under grant assistance from Japan in 1988 by an S-Band Mitsubishi weather radar, RC-34B.This is much more sophisticated with advanced technology, having additional facilities of DVIP and color monitor display for indicating rainfall intensity and recording data for further study and research. Likewise, the S-band Plessey 43-S weather radar at Khepupara, being obsolete after expiry of its operational life, was also replaced under the same assistance in 1988 by an S-Band Mitsubishi RC-34B weather radar, similar to that at Cox's Bazar.[71]

(b) Microwave Link

The interpretation of the observed radar echoes of tropical cyclones used to be sent in plain language to the Storm Warning Centre in Dhaka, using conventional communications like SSB, T.P. and telephone. Since their commissioning, such conventional communication links remain either disturbed or unserviceable most of the time during inclement weather. Furthermore, the information received does not become available to the cyclone forecasters in real time. This hard reality in the past became a major difficulty in making the best use of the radar echoes obtained from the radar at Cox's Bazar and Khepupara. To overcome this

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[70] ibid.

[71] *Bangladesh Meteorological Department Annual Report* (in Bangali), 1997 p.3

drawback a Microwave Link was established in 1992 between the Storm Warning Centre (Dhaka) and the radar stations at Cox's Bazar and Khepupara through an assistance grant from the Government of Japan.[72]

With the establishment of the Microwave Link in 1992, it became possible to detect in real time the location, intensity and movement of a cyclone in the Bay of Bengal, when it comes within the range of the radar at Cox's Bazar and Khepupara. The maintenance of continuous monitoring helps forecasters to get the track of the cyclone indicating its expected time and place of landfall. Thus, this new advanced communication facility for receiving radar echoes was yet another step forward toward improving the cyclone (as well as El Niño/La Niña) warning system of the Bangladesh Meteorological Department.[73]

(c) Storm Warning Center (SWC)

The Storm Warning Centre (SWC) is the National Forecasting Centre of the country and is the nerve centre of the Bangladesh Meteorological Department (BMD). It is situated on the first floor of the Technical Building of the Department within the Meteorological Complex at Agargaon, Dhaka. It also has the Regional Meteorological Centres which control all the field offices and the observatories in the Dhaka and Rajshahi divisions. It also controls the radar station, Dhaka and has a Microwave Link with radar stations at Cox's Bazar and Khepupara. The operational unit of the SWC performs the following functions:

- Preparation and analysis of all weather charts and their interpretation around the clock.
- Issuance of routine weather forecasts, special weather bulletin for cyclones and warnings for nor'westers, tornadoes, heavy rainfall, etc. for the benefit of public, farmers, shipping and aviation.[74]

4.1.3 Bangladesh Water Development Board (BWDB)

This Board initially started in 1959 as the East Pakistan Water Development and Power Development Authority (EPWAPDA) for the purpose of achieving mainly self-sufficiency in food production and for poverty alleviation through flood control and a drainage system all over the country. Subsequently, after the liberation of Bangladesh, EPWAPDA was separated into two autonomous bodies. The Bangladesh Water Development Board (BWDB) is one of them, which has been working on flood control,

[72] ibid. p.5

[73] ibid. p.8

[74] ibid.

water research development, waterlogging, salinity and the maintenance of river channels. In addition, the Board also has expertise in forecasting floods and issuing flood warnings by studying water levels both inside and outside the country.[75]

4.1.3.1 Major Activities

Under the supervision of the Surface Water Hydrology-2, the Flood Forecasting and Early Warning Division (FFEWD), the Bangladesh Water Development Board manages a Flood Information Center (FIC) that produces and disseminates daily river-stage (water-surface elevation) readings and forecasts for the following 24 and 48 hours through its daily bulletins. More than 48 rainfall and 60 river-stage stations are connected to the FIC by wireless. The stations, well distributed around the country, collect current information about local rainfall and river stage conditions. In addition, there are 13 boundary stations to record the inflow and outflow of the country's three major river systems.[76]

Upon receiving the data from the field offices, the FIC processes and analyses the information for inclusion in the bulletin. The FIC also receives weather reports from the Bangladesh Meteorology Department and the Space Research and Remote Sensing Organization (SPARRSO). Using this information, FIC completes flow-simulation runs and produces two types of bulletin. One is dedicated to river-stage and catchment-rainfall records for the previous three days in tabular form. The data is presented for four basins: the Brahmaputra, Ganges, Meghna and Southeastern Hill basins. The other is a brief narrative description of the statistics and for forecasts of the river situation for the next 24 and 48 hours.[77]

In the bulletin, river levels higher than the danger level are underlined in red. As defined in the FIC bulletin, the danger level of river indicates that flooding is likely to occur and that it may damage crops and homesteads. For a river having no

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[75] *Bangladesh Water Development Board Annual Report*, 1996, p.18.

[76] Seminar on Flood Forecasting of Bangladesh, December 1997, p.43.

[77] ibid, p.52

embankment, the danger level is about the annual average flood level. For an embanked river, the danger level is fixed slightly below the design flood level of the embankment. The danger level is defined for a particular measuring station for the hazards of the area in its immediate vicinity.[78]

The FIC distributes the bulletin among various government departments and ministries such as Agriculture, Health, Relief and Rehabilitation, the Disaster Management Bureau and the Presidential Secretariat. The bulletin is also made available to the public media such as radio and TV. Some international agencies and research organizations like the BARC (Bangladesh Agricultural Research Council), FAO, WHO, USAID, UNICEF and the World Bank receive the bulletin from the FIC.[79] However, the FIC does not have the specific task to work on the nature and impacts of El Niño and La Niña events. But when a report on floods has been compiled, if it finds any indication of an El Niño/La Niña episode, the FIC would take all necessary initiatives to forecast the event through appropriate channels.

4.2 Analogy of National and International Forecasting

In the following paragraphs an attempt has been made to highlight "forecasting by analogy" of El Niño impacts in Bangladesh. The discussion is based on the information generated by scientists working in SPARRSO, BMD, DMB and BWD in a Bangladesh context. This is then followed by discussion in an international context.

4.2.1 National Perspectives

Until 1987, the existence of El Niño events was almost unknown to the public in Bangladesh. Knowledge of it was confined to the scientists working in climate-related organizations. At the initial stage of this period, most of the information generated on El Niño and La Niña impacts in Bangladesh was by our scientists whose research work was based on secondary information and done mainly on personal interest. Subsequently, available technology made it possible for them to generate primary data through satellite imagery and helped them to analyze and forecast the events with a national perspective.

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[78] ibid.

[79] ibid, p.31

Mandal,[80] in 1992 suggested a negative correlation between tropical cyclones over the Bay of Bengal and warm ENSO events, with rainfall deficit over India and Bangladesh during the 1951-87 period. This was followed by another pioneering work by Ahmed[81] showing a decreasing trend of rainfall during El Niño years in all the seasons, while Choudhury[82] proposed that "a study of ENSO phenomena might lead to a way of predicting the trends of weather and climate in Bangladesh." Following this hypothesis, Ahmed et al.,[83] found a relationship of ENSO with drought and deficit rain over Bangladesh.

(a) Rainfall and ENSO

They supported this further in a study of the rainfall patterns of Bangladesh over a period of 43 years (1950-92). The rainfall data at different stations were collected by the Bangladesh Meteorological Department. The years of occurrence of El Niño up to 1987 were taken from Mandal's study (1989) and indications of recent events were obtained from the monthly ocean reports of the El Niño Monitoring Centre of the Japan Meteorological Agency.[84] At first four stations were selected from four climatic zones of Bangladesh and classified according to the total rainfall received annually, based on the following criteria:

(i) Lowest rainfall (<1200 mm)

(ii) Moderate rainfall (1200-1500 mm)

(iii) Medium rainfall (1500-1800 mm)

(iv) Heavy rainfall (>1800 mm)

The selected stations were (i) Jessore, (ii) Dhaka, (iii) Barisal, and (iv) Srimangal because they have the best continuous sets of data, relatively speaking. In the first phase, the total yearly rainfall data from of these stations were examined in a time-series plot (Fig.3). In the second phase the rainfall of the four sub-zones were studied season by season, e.g., pre-monsoon (March-May), monsoon (June-September), post-monsoon (October-November) and winter (December-February), taking the mean of the various seasons separately for every year

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[80] Mandal, G.S, "Low Frequency Oscillations and Seasonal Variability of Tropical Cyclones in the North Indian Ocean," (IWTC-II). WNIO/TD-No.319, 1989. pp.342-350.

[81] Ahmed, A.S.MS, "Climatological study in Bangladesh and possible Correlation with El Niño/Southern Oscillation" M.Sc.Thesis, University of Dhaka,1993, p.42

[82] ibid, p.46

[83] Ahmed et al., "El-Niño Southern Oscillation and Rainfall variation over Bangladesh." *Mausam* Vol.47(2), 1996 pp. 157-162,

[84] ibid., p.160

and making a time series plot. In the time-series analysis, all the data were converted into a normalized form. The mean values for 43 years (1950-1992) of the different stations were first determined and the standard deviations then calculated. The deviation from the mean of each reading divided by the standard deviation was taken as the normalized value. This was then plotted with respect to a time-series graph. The years where data for several months were missing were omitted from the yearly graph.[85]

Fig. – 3

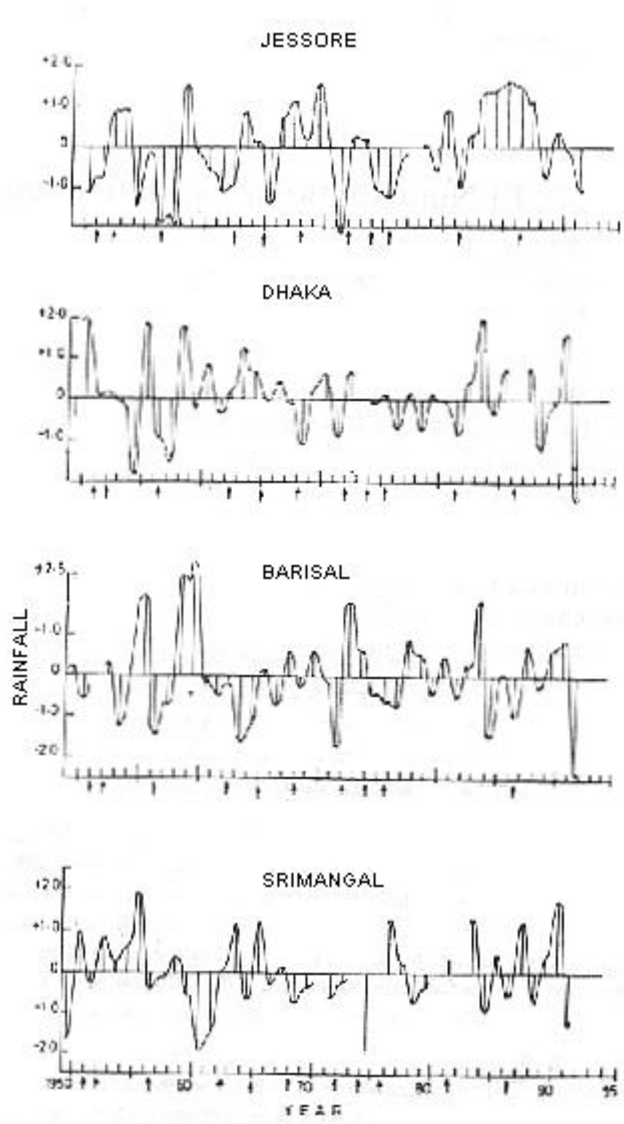

Fig.- 3: Time Series Plot of Yearly Rainfall

[85] ibid., p.158

As depicted above, the time-series graph of yearly rainfall for four stations for the 43-year period (1950-92) showed a negative or decreasing tendency during ENSO events for 70% of the events at Jessore and for 67% of the events at Dhaka, Barisal and Srimangal. There was an increasing tendency for 30% of the events at Jessore and for 22% of the events at Dhaka, Barisal & Srimangal (Table 17).

Table 17. The Study of Yearly Rainfall

Name of Station	Small Variation Tendency	Number of El Niño Years accounted events (1950-92)	Negative* or decreasing tendency events	Positive* or increasing tendency events
Jassore	0	10	70	30
Dhaka	11	9	67	22
Barisal	11	9	67	22
Srimangal	11	9	67	22

* % of total El Niño years.

Source: Ahmed et al., "El Niño-Southern Oscillation and Rainfall variations over Bangladesh." *Mausam* Vol. 47(2), 1996 pp. 157-162.

In a similar fashion, the time-series graphs of mean rainfall of the different seasons, (pre-monsoon, monsoon, post-monsoon and winter) for the four stations have been studied separately and were depicted earlier in Section 3.

The mean annual and seasonal rainfall anomaly for the ENSO years (11 events) ENSO (+1) years and ENSO (-1) years are shown in Tables 18 (a-d). The negative anomaly during ENSO years comes out to be large, compared to the years before and after ENSO. Tests of significance have been performed for the variations, showing that the anomaly of rainfall in El Niño years throughout the country was significant.[86] The data of the year of the severe El Niño (1982-83), where other meteorological phenomena have been known to exhibit large perturbations, were examined carefully. However, they did not show excessive variations when compared to other El Niño years. The yearly pressure and temperature data did not show any particular variations with El Niño.

[86] ibid.

Table 18(a). Yearly Rainfall: Study of Mean Rainfall Anomaly

El Niño Year (-1)	Yearly rainfall anomaly				El Niño Year	Yearly rainfall anomaly				El Niño Year (+1)	Yearly rainfall anomaly			
	Jessore	Dhaka	Barisal	Sri-mangal		Jessore	Dhaka	Barisal	Sri-mangal		Jessore	Dhaka	Barisal	Sri-mangal
1950	73.46	-	101.93	-485.66	1951	-315.54	-	-238.07	355.33	1952	-190.54	-	-	62.66
1952	-190.54	-	-	- 62.66	1953	315.46	-147.27	122.93	312.33	1954	333.46	251.73	-554.07	119.33
1956	13.46	411.73	864.93	678.33	1957	-566.54	-527.27	-632.07	-90.66	1958	-615.54	-710.27	-333.07	15.33
1962	-324.54	-295.27	-200.07	-434.66	1963	-258.54	-109.27	-79.07	42.33	1964	349.46	229.73	-719.07	425.33
1964	309.46	229.73	-719.07	425.33	1965	94.46	35.73	-492.07	-189.66	1966	-393.54	-166.27	60.93	447.33
1968	449.46	-186.27	290.93	71.33	1969	115.46	-541.27	-73.07	-225.66	1970	562.46	-86.27	278.93	-90.66
1971	-	391.73	21.93	-	1972	657.54	-273.27	725.07	-422.60	1973	135.46	387.73	739.93	-147.60
1974	94.46	-	237.93	-	1975	-302.54	63.73	-234.07	-884.66	1976	-366.54	156.73	290.07	1026.33
1975	-302.54	63.73	-234.07	-884.60	1976	-366.54	156.73	-290.07	-	1977	-45.54	-220.27	-280.07	415.33
1981	206.46	87.73	184.33	-53.66	1982	-268.54	-272.27	-274.07	-35.66	1983	126.46	283.73	48.93	601.33
1986	553.46	397.73	-27.07	122.33	1987	513.46	104.73	-487.07	-358.66	1988	259.46	396.73	226.93	494.33
Mean	92.26	137.60	52.23	19.44	Mean	-34.70	-150.90	-309.30	-42.84	Mean	10.46	52.33	-82.07	294.87

Table 18(b). Mean Yearly Rainfall Anomalies for 4 Stations

El Niño Year (-1)	Mean of rainfall Anomalies for 4 stations	El Niño Year	Mean of rainfall Anomalies for 4 stations	El Niño Year (-1)	Mean of rainfall Anomalies for 4 stations
1950	-103.42	1951	-66.09	1952	-126.60
1952	-126.60	1953	150.86	1954	37.61
1956	492.11	1957	-454.13	1958	-407.05
1962	-313.63	1963	-101.13	1964	71.36
1964	61.36	1965	-137.88	1966	-12.88
1968	156.36	1969	-181.13	1970	166.11
1971	206.83	1972	-190.85	1973	278.88
1974	166.19	1975	-339.38	1976	131.60
1975	-339.37	1976	-166.62	1977	-32.63
1981	106.21	1982	-212.63	1983	265.11
1986	261.61	1987	-56.88	1988	344.30

Table 18(c). Seasonal Rainfall Anomaly During El Niño Years

Station	Pre-monsoon			Monsoon			Post-monsoon			Winter		
	Y(-1)	Y	Y(+1)	Y(-1)	Y	Y(+1)	Y(-1)	Y	Y(+1)	Y(-1)	Y	Y(+1)
Jessore	19.15	-69.66	48.87	64.37	-29.62	-48.46	53.55	-54.40	24.04	-6.14	-5.40	-3.67
Dhaka	18.82	-56.56	76.53	100.10	-0.82	-91.12	49.77	-64.00	67.70	-2.78	0.38	3.52
Barisal	27.82	-59.04	-7.38	-2.57	-107.40	-111.40	29.86	-83.43	25.44	-3.50	-5.11	-1.48
Srimangal	-124.50	-94.26	7.47	-15.54	-12.60	232.75	42.01	-24.24	57.70	-7.85	-5.51	3.33

Table 18(d). El Niño Years Under Study

El Niño year (-1) Y(-1)	El Niño year Y	El Niño year (+1) Y(+1)
1950	1951 (m)	1952
1952	1953 (m)	1954
1956	1957 (s)	1958
1962	1963 (m)	1964
1964	1965 (m)	1966
1968	1969 (m)	1970
1971	1972 (s)	1973
1974	1975 (m)	1976
1975	1976 (m)	1977
1981	1982 (s)	1983
1986	1987 (m)	1988

m = moderate

s = severe

Source: Ahmed Sabbir, ASM, "El Niño-Southern Oscillation and Rainfall variation over Bangladesh," p.162

From the findings of the above tables, the following conclusions may be drawn:

- El-Niño Southern Oscillation (ENSO) events are found to have an important modulating effect on tropical phenomena. A study of the rainfall patterns over Bangladesh for a period of 43 years seems to support this. There is a definite correlation of ENSO with deficit rainfall in this area.
- The yearly rainfall at four stations in different climatological areas shows a decreasing tendency for most of the ENSO events (66%-70% of the time).
- The time-series graphs of the mean rainfall during the different seasons (pre-monsoon, monsoon, post-monsoon and winter) studied separately for the four stations again

showed a negative correlation with warm ENSO events, varying from 60%-80% of the time, except for Dhaka where the yearly graph shows a clear decrease.

- The mean rainfall anomaly of the annual and seasonal rainfall for the warm ENSO years as compared to ENSO (+1) and ENSO (-1) year shows a definite negative value.
- Other parameters of the monsoon circulation need to be examined to get a better understanding of the modulating effect of ENSO.

(b) El Niño and Monsoon Conditions

During El Niño years, Bangladesh is affected by deficit rainfall or bad monsoon conditions, as suggested in the statistics given in Table 2 in Section 3. They show that eight El Niño events occurred from 1953 to 1997, when Bangladesh experienced deficit rainfall, of which 1957, 1982 and 1997 were the severe deficit years.

Choudhury (1999) studied the correlations between the rainfall of selected flood years (1987, 1988 and 1991) and the SOI. The results, given in Tables 19-22, show that the SOI has a medium correlation with rainfall and its deviation from normal during flood years. The values of the SOI for the months of January-April can be used to forecast the monthly rainfall during June-September.[87]

Table 19. Correlation of SOI with Actual Rainfall and % Deviation of Rainfall (Month by Month)

	1987	1988	1991
Correlation between % Dev. of rainfall and SOI for June-September	0.3	-0.4	-0.9
Correlation between actual rainfall and SOI for June-September	-0.6	-0.6	-0.5

Df=2

Table 20. Correlation of SOI with Actual Rainfall and Deviation of Rainfall (%) during the SW Monsoon (random) (Month by Month)

Correlation with % dev. of rainfall	Correlation with actual rainfall
-0.602016	-0.615387

Df=10

[87] ibid. p.5

Table 21. Year-wise Correlation between January-April SOI and June-September Rainfall (Month by Month)

1987		1988		1991	
Correlation of SOI		Correlation of SOI		Correlation of SOI	
With rainfall	With % dev. of rainfall	With rainfall	With % dev. of rainfall	With rainfall	With % dev. of rainfall
0.39680	-0.451767	-0.442249	0.80743	0.178099	-0.585869

Df=2

Table 22. Correlation between January-April *SOI* and June-September Rainfall (Month by Month)

Correlation of SOI	
With rainfall	With % dev. of rainfall
-0.181215	-0.547669

Df = 10

The above correlation between rainfall and SOI also reveals that El Niño and La Niña events have some effect on the rainfall conditions in Bangladesh. The correlation between the duration of the SW monsoon and the SOI has been studied for ten stations of Bangladesh. The duration of the SW monsoon for the 1958-1987 period has been taken from the study of Ahmed and Karmakar[88] (1993). Table 23 shows the correlation coefficients between the 3-year moving average of duration of the SW monsoon and the annual mean SOI. The significance of the correlation coefficients has been determined using the of student's t-test. The duration of SW monsoon has a positive correlation with the annual mean SOI, but the correlation coefficients are not statistically significant except at the Sylhet station.

[88] ibid, p.7

Table 23. Correlation Coefficients between the 3-year Moving Average of the Duration of SW Monsoon and the Annual Mean SOI

Stations	Correlation coefficients
Dhaka	0.20302
Cox's Bazar	0.21862
Sylhet	0.36859*
Rangpur	0.27160
Khulna	0.21899
Barisal	0.19670
Chittagong	0.31909

* Statistically significant at 95% level

(c) El Niño and Nor'westers

The correlation between the seasonal thunderstorms/Nor'westers of Bangladesh during March-May of the 1972-1988 period and the SOI has been studied. Fig. 4 gives the temporal variation of the 3-year moving average of seasonal Nor'westers and the annual mean value of the SOI. The figure shows that the frequency of Nor'westers is negatively correlated with the SOI and the correlation coefficient is –0.71935, which is statistically significant at the 99% level.

Fig. 4

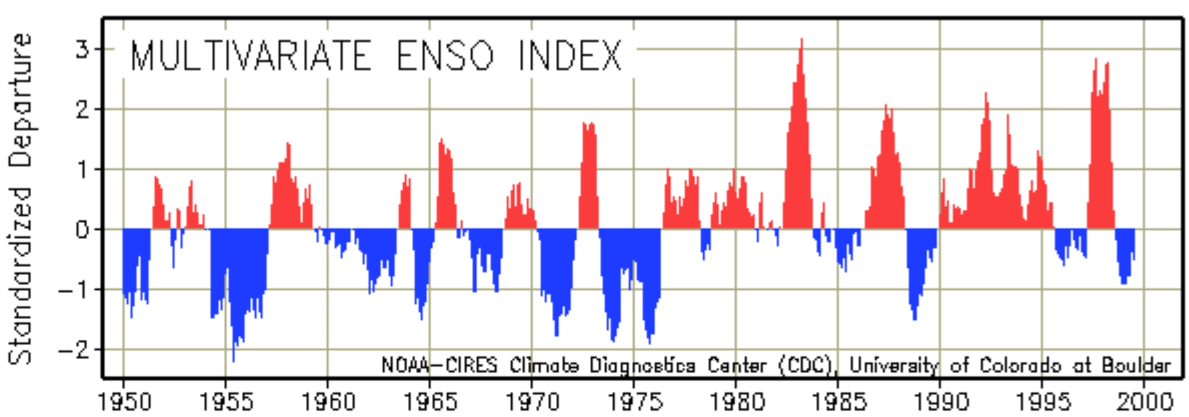

Fig. – 4: Monthly Values from January 1950 through March 1998 of the *SOI*

(d) El Niño and Cyclones in the Bay of Bengal

The frequency of cyclonic disturbances (CD), depressions (D), cyclonic storms (CS) and severe cyclonic storm (SCS) in the Bay of Bengal during the El Niño years is given in Table 24.

Table 24. Frequency of Cyclonic Disturbances (CD), Depression (D), Cyclonic Storm (CS) and Severe Cyclonic Storm (SCS) in the Bay of Bengal During the El Niño Years (CD=D + CS + SCS)

El Niño year	CD	D	CS	SCS
1953	7	6	1	0
1957*	5	4	1	0
1963	7	5	1	1
1972*	13	6	3	4
1976	12	4	7	1
1982*	10	6	0	4
1987	4	1	1	2
Long-term mean frequency	9.99	5.85	2.65	1.47

* = strong event

Table 24 shows that the frequency of CD, D, CS and SCS is lower than the long-term mean frequency in most of the El Niño years. The correlation between the frequency of the above disturbances and the SOI has also been studied and the correlation coefficients are found to be very small (e.g., r=0.23561 for SCS). These are not statistically significant.[89] Fig. 5 shows the sea surface temperature (SST) anomalies during El Niño and La Niña events since 1982.

[89] ibid., p.8.

Fig. 5

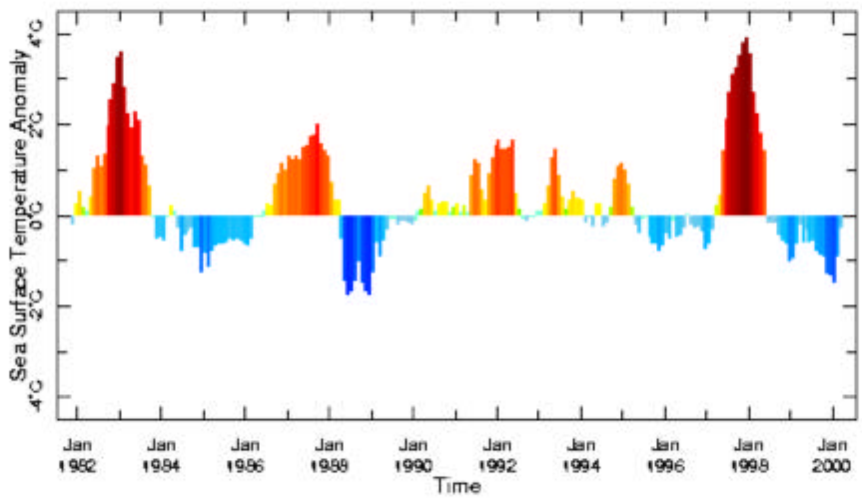

Fig. –5: Sea-Surface Temperature Anomalies During El Niño and La Niña Events Since 1982.

The data collected during a field survey to identify the type of events that occurred and their impacts on Bangladesh has been compiled in Table 25. The table shows that Bangladesh has experienced as many as 12 El Niño events and 7 La Niña episodes from 1951 to 1998. Among them, 5 El Niño events were very strong and 5 were moderate and 2 were weak. During this span of time, 7 La Niña events affected the country, 4 of which were very strong, 2 were moderate and 1 was weak. This table supports the findings of the various studies undertaken on El Niño and La Niña episodes by scientists from the afore-mentioned organizations.

Table 25. Types of Event Occurred and their Magnitudes in Bangladesh

Years	**Disasters condition**	**Type of events**	**Magnitude**
1951	Drought	El Niño	Moderate
1954	Flood	La Niña	Moderate
1955	Flood	La Niña	Severe
1957	Drought	El Niño	Severe
1958	Drought	El Niño	Moderate
1960	Cyclone	---	Moderate

1961	Drought	---	---
1963	Cyclone	---	---
1965	Cyclone	---	---
1970	Cyclone	La Niña	Severe
1972-73	Drought	El Niño	Severe
1973-74	Drought	La Niña	Moderate
1974	Cyclone	La Niña	Weak
1976	Drought	El Niño	Moderate
1979	Drought	El Niño	Weak
1982-83	Drought	El Niño	Severe
1986	Drought	El Niño	Weak
1987-88	Drought	El Niño	Severe
1988	Flood	La Niña	Severe
1991	Cyclone	El Niño	Severe
1995	Cyclone	El Niño	Severe
1997-98	Drought	El Niño	Severe
1998	Flood	La Niña	Severe

Sources: (i) BBS 1990, Monir-uz-Zaman: CDI, Kafiluddin 1991 ADB 1991a, Mahlanobis 1927

(ii) WMO Statement on the Status of the Global Climate in 1998

(iii) Field Survey, 1999

Although El Niño forecasting in Bangladesh by concerned agencies does not correspond exactly to the findings, the relationship of the similarity of two factors is indeed positive. Since the technology available in Bangladesh is not enough to unfold the mysteries of El Niño episodes, we have to share ideas and technology from developed countries in order to prepare for the negative impacts of El Niño events in the country. Regular exchanges of information with specialized organizations in developed countries and a proper (e.g., improved) understanding of the mechanism of ENSO phenomena would enable us to better forecast, monitor and plan well ahead of time in order to cope with such national disasters as cyclone, drought, and flood.

4.2.2 International Perspectives

Many organizations and agencies are engaged in monitoring and forecasting meteorological phenomena and natural disasters including El Niño/La Niña episodes in a global context. Some of the most notable ones at this time are listed below:

- The World Meteorological Organization (WMO)
- The Bureau of Meteorology, Australia (BOM)
- The Japan Meteorological Agency (JMA)
- The National Center for Atmospheric Research (NCAR)

Historical evidence shows that the El Niño phenomenon had been occurring every two to ten years, since reliable worldwide recordings by instruments began in 1860.[90] Over the years, scientists have discovered an increasing trend of El Niño events and that their impacts have been several times greater than the past.

In trying to improve their power of prediction, researchers are building on a scientific investigation that began in the 1920s, when Sir Gilbert Walker[91] linked the swings in atmospheric pressure over the Pacific Ocean to a calamitous failure of the Indian monsoon 50 years earlier. In the late 1960s, University of California Los Angeles (UCLA) meteorologist Jacob Bjerknes[92] suggested that El Niño is governed by the same swings in atmospheric pressure. Many scientists are now convinced that high pressure in the eastern Pacific Ocean sends trade winds blowing to the West under non-El Niño conditions. Because these winds push water before them like an invisible plough, the sea's surface actually measures about a half-meter higher around Indonesia and Australia than it does off the coast of Peru. When the pressure drops and trade winds slacken, the water sloshes back "downhill," to the east.

From our view, during the last two decades a great deal of investment and investigation has been made by the World Meteorological Organization (WMO) in monitoring and in research to enhance the capacity to predict El Niño events. Since then the WMO has played a leading

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90 World Meteorological Organization, "Statement on Global Climate." 1998. p.4

91 David Gordon, "Hot on El Niño's Trail Environment: Warning signs of African drought found half a world away." *Newsweek*, October 31, 1994, p. 47.

92 Madelene Nash, "Fire and Rain: El Niño's Fury, Deluge from La Niña." *Time*, April 20, 1998, pp.34-39

role, with the support of UNESCO/IOC and UNEP, in the scientific and technical assessments of the phenomenon. The 1997-98 El Niño received widespread attention for two important reasons (WMO, 1999). First, it was in many ways one of the most intense El Niño events of the century and global surface temperatures were among the highest. Secondly, new research and improved observational capabilities greatly improved the analyses and forecasts of the major climate prediction centers and national meteorological services, which were then widely reported in the media.[93] With the advent of high-speed computers, the complex interactions and massive amounts of data could be put together to provide a relatively improved picture of the phenomenon. This has enabled the scientists to predict phenomena somewhat better than before (e.g., see Barnston et al., 1999).

The eastward flow of the ocean is central to the physics that drives El Niño, according to Nicholas Graham.[94] The sloshing in the ocean sends Kelvin waves across the ocean like ripples in a pond. These waves, in turn, push down the thermocline, a layer between the cooler water and the warmer surface water. As the thermocline becomes depressed to greater depths, temperatures at the sea's surface rise, and an El Niño begins.

These subsurface Kelvin waves explain more than the origin and propagation of El Niño. They also explain how El Niño ends. When the waves first hit the South American coast, some reflect back like the sound bouncing off a wall. When the reflected waves reach Asia, they rebound again. But this double bounce inverts their effect, instead of depressing the thermocline, these twice-reflected waves now lift it up. Cool water dilutes the warmer water at the surface, causing a temperature drop in the eastern Pacific and that decrease, if big enough, eventually becomes a La Niña. Thus, observed Ants Leetmaa,[95] Director of the National Climate Prediction Center, "each El Niño contains the seeds of its own destruction."

Once El Niño has passed, sea surface temperature trends and atmospheric circulation reverse direction again. If the swing back is dramatic, it creates a condition called La Niña–less frequent and, therefore, less studied than El Niño. During La Niña, the warm waters off Latin America are replaced by unusually deep cold upwelled water, known as the *'equatorial cold tongue*,' chilling sea surface temperatures by up to 7° C below El Niño-related high temperature levels. Westbound trade winds blow stronger than usual and cycles of flooding and drought are often inverted. Heavier rains fall over the western Pacific, southern and eastern Asia, and northern Australia and as far west as southern Africa. High atmospheric pressure over the central Pacific weakens the subtropical jet stream, allowing powerful Atlantic hurricanes to form. On 24 September 1998, for the first time this century, four

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[93] ibid.

[94] ibid., p. 37.

[95] ibid., p. 38.

Atlantic hurricanes - including Mitch - were actives at once. “Such enhanced hurricane activity,” says the World Meteorological Organization, “is consistent with developing La Niña conditions.”[96]

A most remarkable achievement for in El Niño prediction was the support by the US National Oceanic and Atmospheric Administration (NOAA) for the anchoring of 70 buoys across the equatorial Pacific to provide signals of the onset of an El Niño. This sophisticated system is known as the Tropical Atmosphere-Ocean (TAO) Array and was completed in 1994. These buoys measure surface air and wind conditions and sea temperatures at depth. Combined with data from the French-American TOPEX-Poseidon satellite, which monitors ocean circulation and changes in sea heights, climate scientists are better informed than ever before. NOAA estimates that improved long-range forecasts could save producers and consumers in the US alone between US$ 240 to 324 million every year. Nevertheless, accurate forecasting of specific El Niño effects remains problematic. As Giovanni Rufini,[97] coordinator of the Brussels-based Voluntary Organizations in Cooperation in Emergencies (VOICE), points out “several predicted droughts have instead turned out to be floods,” although he agrees that continued development of such systems is “vital.” This innovative technology has for the first time ever, *enabled the scientists to monitor the latest El Niño and to identify potential accompanying droughts and floods by up to six months in advance, giving time to prepare.*

By tracking ocean temperatures, salinity levels and wind patterns, it is now possible to tell when El Niño is developing several months before it impacts South America. The commission currently issues bi-monthly bulletins to forewarn fishermen, farmers and government officials about such conditions.

4.3 Forecast of El Niño as early as October 1996

The sequence of events, starting in early 1996, is well documented by the alternating relatively cold (La Niña) sea surface temperature and warm (El Niño) sea surface temperature in the equatorial Pacific.

The El Niño episode developed very rapidly throughout the central and eastern tropical Pacific Ocean during April and May 1997, reaching a strong intensity by June 1997. During the second half of the year, this episode became even more intense than the major 1982-83 El Niño, with sea surface temperature (SST) anomalies across the central and eastern Pacific

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[96] ibid., p. 39

[97] Op. Cit.

reaching more than 2.5°C above normal. Choudhury[98] (from SPARRSO) in 1997 first officially forecast the impacts of El Niño in Bangladesh. Although the forecast was in no way perfect, it was quite useful and satisfactory. The forecast was given to the concerned authorities for necessary action.

The forecasts from most major prediction centers indicated that the episode would continue until March-May 1998, followed by a weakening of the warm episode. Some models indicated a switch to a cold event (La Niña) beginning in the July-September 1998 period. The Bangladesh Meteorological Department predicted its impacts on Bangladesh and circulated its projections in the media in due course.

4.3.1 Realistic Obstacles that Prevented Theoretical Actions

Information collected through satellites is being processed, tabulated and analyzed manually. This traditional practice is no doubt one of the major obstacles that prevented the flow of information in due time to the concerned organizations. This obstacle could be avoided, and the collected information can be processed and analyzed, if modern technology were available in those organizations. Moreover, skilled and competent personnel are not available in the respective sections; this sometimes makes the information non-operational. Also, the lack of awareness of the subject and a sense of disbelief might have been other obstacles in the process of preparing for the forecast impacts.

Traditional methods of weather forecasting are still used in practice in Bangladesh, in which various weather charts are normally analyzed on a routine basis to identify the nature of events. These limitations are some of the major obstacles that might have prevented the flow of information.

4.3.2 Can El Niño Considerations Be added to a National Disaster Plan?

El Niño events have generated or at least been associated with climatic anomalies not only in the areas where they occur but have also exerted their adverse influence in the overall climatic situation of Bangladesh. These anomalies create unusual disasters seriously affecting infrastructure as well as socio-economic conditions of our country. Scientists working on El Niño events inform us of the consequences and likely threats of the disaster and strongly recommend looking into considering El Niño in disaster planning for the country in the future.

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[98] Choudhury, A. M: Effect of El Niño Being Studied to Help Farmers Face Weather Change. *The Daily Star*, 6 July 1998, Dhaka, 1998.

Considering the impacts of El Niño and La Niña in our country, the government should include the issue of El Niño in its plans to provide adequate arrangements to deal with all aspects of its possible consequences. Thus, in framing national disaster management plans, careful consideration of El Niño needs to be given by establishing specialized agencies. The study of El Niño will remain inadequate if such policy decisions are not taken in the near future. Consequently, the loss of life, human resources and property will increase, and the nation as a whole will suffer. The Government of Bangladesh is paying attention in its Fifth Five-Year Plan to the appropriate policy and strategy formulation for the purpose of coping with natural disasters, including El Niño and La Niña events.

The El Niño consideration for Bangladesh weather systems, as discussed above, indicates an erratic relationship with a good correlation recognizable in the case of monsoon rainfall. As our economy is still heavily based on monsoon rainfall, it is, therefore, important to consider El Niño events in formulating and designing our national plans to avoid its negative impacts.

4.3.3 Strengths and Weaknesses of Government System Responses to El Niño Related Climate Anomalies

The Bangladesh government is firmly committed to coping with any type of natural disaster. This commitment has been reflected by the creation of a number of specialized organizations for continuous monitoring, forecasting and appropriate policy action. Among them, SPARRSO, BMD and BWDB are assigned to monitor, forecast and undertake research on various types of natural disaster. These organizations are equipped with modern technology (for example, Advanced Meteorological Satellite Ground Station (AMSGS), Landsat Satellite Ground Station (LSGS), Digital Image Processing System (DIPS) and a Geographical Information System (GIS). A network of 35 Synoptic Surface Observatories (SSO), 11 Pilot Balloon Observatories, 14 Agro-meteorological Observatories, 3 Radar Stations and one Automatic Picture Transmission (APT) ground receiving observation. Besides, there is the Storm Warning Center (SWC) and the Flood Information Center (FIC). While the Disaster Management Bureau (DMB) has been assigned to make people aware of disaster-prone areas and to provide training to the public, the private sector and NGOs cope with disasters. These initiatives have helped the government to introduce a preparedness system through relevant agencies since 1974.

As a result of governmental initiatives, more advanced and sophisticated technological systems and techniques are gradually replacing the old methods of climate and weather forecasting. BMD now has a modern meteorological communication facility known as the National Meteorological Communication Centre (NMCC) which is linked up with a global Tele-Communication System (GTS) through a line capacity of 2400 bps. A computer-based and highly automated system of flood forecasting and warning operations known as FFWC has been established under the BWDB. The GOB has so far constructed 1841 cyclone shelters and 200 flood shelters as a part of its structural mitigation measures. In addition, about 3931 km-long coastal embankment to protect coastal lands and drainage channels of a total length of 4774 km have been constructed. Safety mechanisms have been better tuned and better targeted.

Moreover, the standing orders have been prepared with the avowed objective of making the affected people understand their duties and responsibilities regarding disaster management at all levels. All ministries, divisions, departments and agencies prepare their own action plans with respect to their responsibilities under the standing orders for efficient implementation. The National Disaster Management Council (NDMC) and the Inter-Ministerial Disaster Management Coordination Committee (IMDMCC) ensure coordination of disaster-related activities at the national level. Coordination at the district, *Thana* and union levels is carried out by the respective Disaster Management Committees. The Disaster Management Bureau renders assistance to them by facilitating the process.

The ministries, divisions, departments and agencies organize proper training of their officers and staff employed at district, *Thana*, and union and village levels, according to their own action plans so that they can assist in rescue, evacuation and relief work at different stages of disaster. The local authority arranges for the preparedness for emergency steps to cope with the disaster and to mitigate distress without having to wait for government help.

Besides these initiatives, several weaknesses persist in the government response system to the climate-related anomalies. The most pertinent weaknesses are, for example, the lack of good communication, the lack of proper co-ordination among the concerned specialized organizations, bureaucratic entanglements, resource constraints, a weak technology base and an ineffective system of operation. These limitations keep certain levels of technology too constrained to identify the most comprehensive climate related anomalies.

4.3.4 Influence of the 1997-98 El Niño on the Response to the Forecast in Early 1998 of an Expected La Niña Event

The experience of the 1997-98 El Niño was greatly helpful in the early forecasting of the 1998 La Niña in Bangladesh. The first warning of El Niño was made in March 1997 and the event continued up to April 1998. Monsoon rainfall increased abruptly after June 1998 (once El Niño ended). This caused unprecedented flooding in Bangladesh from July to September 1998. This was not only an unprecedented flood in the history of Bangladesh but also one of the most prolonged floods. Moreover, during the 1997 El Niño period, storms in the Bay of Bengal were different than normal, and the frequency of the storms showed erratic behavior.

As there is a reasonable possibility of a La Niña starting after an El Niño, scientists in Bangladesh forecast an expected La Niña episode in 1998. This indicates that the climate and weather patterns in Bangladesh have a strong relationship with ENSO extreme events. Nevertheless, this relationship with El Niño and La Niña needs to be given serious consideration because our socio-economic structure is based on agriculture, which is heavily dependent on weather.

4.3.5 Achievements in Forecasting by Analogy

The results of research undertaken on the various types of disasters described earlier in forecasting and monitoring indicate that the concerned organizations and their interpretations appear to be effective. Satellite imagery, immediately after having been received by SPARRSO, was disseminated to the Storm Warning Centre of the Bangladesh Meteorological Department (BMD) in the form of bulletins from time to time beginning on 15 May 1997. As soon as a low pressure system is formed in the southern part of the Bay of Bengal, it turns into a tropical cyclone. In addition, the high and low-resolution imagery is also sent to the BMD as soon as it is received. Since the cyclones form in the distant sea, outside the range of the meteorological observation network and the coastal radar system, the early warning system of the BMD has to depend mostly on the observations by satellites, until each cyclone has moved within the range of the radar systems. SPARRSO monitors each cyclone constantly day and night since its formation by operating the ground station until the cyclone has dissipated. The data and the results of the interpretation are provided to the government and to the highest body of the administration to facilitate the cyclone preparedness program.

4.3.6 Development of Model for Tropical Cyclones

SPARRSO has by now developed a 2-dimensional (2-D) numerical tropical cyclone model. It has five unequally spaced vertical layers: *the boundary layer, one stratospheric layer and three tropospheric layers*. The model extends to 2000 km in the horizontal direction with a grid size of 33 km. The time integration of the prognostic equations is done using a modified leapfrog scheme with a time step of 50 seconds.[99]

Diabatic heating of the cyclone in the model is estimated to form the moisture budget equation with the assumption that the time variation of the mixing ratio is negligible in the cyclone. The vertical distribution of the diabatic heating is determined empirically and thereafter adjusted during the numerical experiments. The above-mentioned scheme takes account of the cumulus heating without application of any cumulus parameterization scheme. The surface drag coefficient is considered to be dependent on the wind speed at the lowest level. The model is axis-symmetric in nature and produces circularly symmetric features of the tropical cyclone.[100]

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[99] SPARRSO, Remote Sensing and GIS in Water Resources and Disaster, January, 1996, p. 9

[100] ibid.

The atmosphere is assumed at rest in the initial state and is excited by a large-scale heating from outside which takes about 4 days to develop a weak vortex (an initial vortex) with maximum tangential wind of 10 m/s and a central pressure drop of about 9 mb. At this stage, the external heating is cut off and the internally produced condensation heating takes over. The model is run for 10 days starting with this initial state. The cumulus convective process becomes active at this stage and the resultant condensation heating soon amplifies it, which intensifies the vortex into a mature tropical cyclone.[101]

The temporal evolution of the maximum tangential wind speed and the radius of maximum tangential wind with reference to the 800 mb level has been observed from the model experiments. The evolution of the central surface pressure drop was analyzed. It was found that after 3 days of integration, the vortex intensified into a tropical cyclone and attained a quasi-steady state. The maximum tangential wind speed at 800 mb reached a peak value of 37 m/s at a distance of 50 km from the center with a pressure drop of about 60 mb at the center.[102]

The low-level vortex structure and its temporal evolution have also been studied. The radial distribution of surface pressure and the tangential wind for time T=0, 2 and 3 days clearly demonstrated the gradual intensification of the vortex into a mature tropical cyclone. The model has successfully simulated the strong low-level inflow with maximum radial wind speed of –6 m/s and the strong divergence in the upper level with maximum outflow wind of nearly 4.5 m/s. The horizontal, vertical and temporal structures of the mature tropical cyclone as simulated in this model are found to be consistent with the observations.[103]

This demonstrates that the model assumptions and physics used in the model closely represent the reality and may be used for developing the 3-D model which will allow investigation into the development of tropical cyclones and their movements under different background conditions.

4.3.7 Impacts of Climate Change

Bangladesh is one of the most vulnerable countries in the world likely to be seriously affected by possible global climate change and the associated sea level rise. A preliminary investigation has been made on the impacts of global warming on cyclone intensity in the Bay

[101] ibid.

[102] ibid.

[103] ibid.

of Bengal and the associated changes in storm surges. Assuming a lower bound of sea surface temperature of 2?C and an upper bound of 4?C, according to the IPCC limits, the corresponding increases in maximum cyclone intensity come out to be 10% and 22%, respectively, with reference to that of a threshold temperature of 27?C. The maximum wind speed of the April 1991 cyclone was about 225 km/hr. If this cyclone had occurred under the above-mentioned two temperatures, then the wind speed would have been 248 km/hr and 275 km/hr, respectively. This increase in wind speed would seriously increase storm-surge heights. A storm surge model developed for investigating the impacts of climate change shows that the maximum storm surge heights for a 10% and 22% rise in wind speed (with respect to the April 1991 cyclone) would increase by about 21% and 48%, respectively. Obviously such an increase in surge heights would lead to much greater coastal inundation.

4.3.8 Climate Variability

This research work described the variability of climate over Bangladesh in recent years with regard to temperature, rainfall, storms, floods and sea level rise. Analysis of temperature for some stations in Bangladesh shows a slight rise in temperature (0.1-2?C) over the last 40 years. Some stations have shown a fall in temperature. There is, of course, a lot of seasonal fluctuations in the rainfall. Analysis of rainfall data shows an increasing trend of rainfall in most of the stations. Analysis of rainfall for the last 40 years has shown a strong negative correlation between El Niño and rainfall and that is pronounced in all the seasons: pre-monsoon, monsoon and post-monsoon. That means that less rainfall tends to occur in El Niño years. There has also been an increase in natural calamities like cyclones in recent years. Cyclone activity was the severest between 1960-1998.[104] There has also been a decline since then, but a storm of great intensity occurred in 1991. There has been an apparent increase in annual flooding recently. On average about 25,000 sq km of the country are flooded annually. In an exceptionally high flood year, as in 1988, about two thirds of the country was flooded. This increase in flooding is perhaps consistent with the model prediction of monsoons shifting northward. The scenario for the Bangladesh coast is consistent with a 0.1-0.2 mm rise per year over the region. There is, however, a need to establish accurate tide gauges. Modelling has shown that for a 30-cm sea level rise, flooding can be worse because an increase in sea level will slow down the flow of floodwater in rivers.[105]

5.0 Policy Implications, Recommendation and Conclusion

5.1 Policy Implications and Recommendation

[104] ibid.

[105] ibid.

Based on the above discussions, it appears that Bangladesh, as a country, is one of the worst victims of natural calamities. El Niño recurs every two to ten years. In the 20th century, as many as twenty-three El Niños have occurred. Among them, four of the strongest ones have struck after 1980. Regardless of El Niño, in almost every year some parts of the country are affected by climate-related natural calamities. Owing to variations in topography and rainfall patterns between the eastern and western zones of the country, some areas can be affected by floods while others can be affected by drought, even in the same year. In fact, the severest floods of the 20th century occurred in September 1988 and July-September 1998. A devastating cyclone struck on 29 April 1991, and more than 138,000 people died. The economic losses amounted to 2.4 billion US dollars. Extensive infrastructure damage amounted to 3.4 billion US dollars because of the unprecedented lengthy flood in 1998. While drought during the dry and early monsoon periods and an unprecedented tornado in April 1989 caused more than 2000 deaths, an additional 10,000 people were injured and 1,000,000 were affected. It seems that Bangladesh has become increasingly prone to more frequent natural calamities.

5.1.1 Consideration of the Country's Geophysical and Socio-economic Setting in Coping with the Problems of Disasters

Geophysical and Socio-economic settings have multi-dimensional influences on El Niño impacts. Therefore, it should be duly considered in conducting any sort of impact study on El Niño or La Niña, and in undertaking any intervention to cope with disaster problems.

5.1.2 Preservation and Documentation of Historical Records on Meteorological Predictions

Although El Niño and La Niña are relatively recent concepts, their impacts have drawn the interest of concerned people of the Indian sub-continent throughout history. Most of their readings are said to be the envy of any scientists at any time. Quite a large number of astronomical, meteorological and agro-meteorological predictions and myths of the history are in existence in the country which should be preserved and documented properly so that they might be used in future studies.

5.1.3 National Policy

There is need for a clear and comprehensive national disaster policy, which will address the total disaster management spectrum, including El Niño and La Niña considerations of all aspects of preparedness. Within this policy, there must be a readiness on the part of the government to institutionalize preventive measures.

5.1.4 Legislative Measures

The Government of Bangladesh should undertake the following initiatives:

1) To formulate a comprehensive plan for disaster management, disaster policy and disaster actions at the earliest possible time

2) To design an appropriate and enforceable legal mechanism for dealing with all types of natural disaster

3) To develop appropriate technology and ensure the collection of relevant data on disaster through the use of satellites and the introduction of a regular system of delivering information to the public through television, radio and other mass media

5.1.5 Assessment and Monitoring

There should be adequate assessments about and monitoring of hazards, disasters and vulnerabilities, so that the need for prevention is accurately identified and disasters defined. This should lead to accurate evaluations of all reasonable disaster prevention projects. In this regard, it is especially important to achieve sensible cost-benefit comparisons; for example, whether, by instituting preventive measures, the nation and community is going to gain more (bearing in mind the project costs), as opposed to the losses which may arise if nothing is done.

The people of Bangladesh, especially the marginal and poorer classes, become severely affected when El Niño droughts and La Niña floods damage crops. Therefore, the concerned government organizations should 1) carefully monitor the development of El Niño and La Niña events and 2) undertake safety measures for protecting food stocks and, if required, import food grains to prevent food crisis and famine.

5.1.6 Planning and Organization

Full and appropriate consideration of all disaster aspects should be given within the National Development Plans, including the immediate and long-term cost-benefit implications of preventive action. In this context, the establishment and maintenance of a permanent disaster management section or center can play a vitally important part. On behalf of the government, the section or center should keep a constant watch on disaster management and identify the need for preventive measures whenever such need may arise. It is then the responsibility of the section or center to advise the government on needs and priorities in the disaster-prevention and disaster-mitigation fields.

There should be an insistence by the disaster management section and center (on behalf of the government) that an effective post-disaster review be undertaken after all major disaster events. This review must include advice to the government on whether, as a result of the particular disaster, further preventive measures are warranted.

Furthermore, a separate cell to be named the *El Niño and La Niña Forecasting Cell* should be created to integrate and coordinate El Niño and La Niña related activities of the concerned agencies. Scientists should be properly trained in predicting and monitoring El Niño and La Niña impacts in Bangladesh.

5.1.7 Enhancing Scientific Research Initiatives

The SPARRSO and the BMD should be well equipped with modern facilities for receiving and forecasting weather and the prospects for disasters and for transmitting to officials and the public information about them and their impacts on economy and the society. Furthermore, research facilities should be enhanced and strengthened, so that impact studies on El Niño/La Niña or on other disasters can be conducted more scientifically. International assistance may play a vital role in this respect.

5.1.8 Public Awareness and Education

Public awareness and education programs should ensure, among other things, that disaster-prone communities are kept aware of the risks and vulnerabilities. In this way, communities are likely to support the need for sensible disaster prevention, if this becomes necessary.

5.1.9 Involving Local People

Neither governments nor aid agencies are equipped to make judgments about how local people should consider their disaster. A participatory process is essential. Public agencies need training in participatory approaches. Senior management should highlight the importance of such participation. Local participation also yields high economic and environmental returns in implementing programs of afforestation, soil management, park protection, water management, and sanitation, drainage, and flood control. Increasing the responsibilities for local government is an important part of this process.

5.1.10 International Assistance

The maintenance of a continuous dialogue with international assistance agencies can also be of immense use. Such a dialogue would help in ensuring an evaluation of responses concerning disaster prevention and in ensuring submission to appropriate assistance agencies.

The SPARRSO and the BMD should have a closer contact with the World Meteorological Organization and other international meteorological agencies.

5.1.11 Developing Regional Framework for Cooperation

El Niño/La Niña and many other natural disasters, including climate-related, have regional or international characteristics in terms of impacts and vulnerabilities. Bangladesh, acting alone, may not be able to cope with such disaster problems. A short-, medium- and long-term Disaster Management Action Plan should be developed within South Asian Association for Regional Cooperation (SAARC) or some other regional framework.

5.2 Conclusion

Under the extreme influences by countless variables including variations in Earth's orbit, the strength of ocean current and possible human influences on the environment, no two El Niño or La Niña events are likely to be identical. Even with a single event, local conditions can change drastically over just a few days. While conditions during the past few events appear to have been more extreme than those of earlier events, the evidence is not conclusive. There is a consensus among climate scientists that El Niño events have become more frequent and progressively warmer over the past fifty years. Beyond that, there is a little agreement, particularly about whether human activity (e.g., the global warming issue) might be exacerbating their effects.

In the past 98 years there have been 23 El Niños and 15 La Niñas, according to NOAA's definition. Other organizations depending on their definitions have a slightly different count. Of the century's ten most powerful El Niño events, the four strongest occurred after 1980. No one knows, however, whether this indicates a trend or it is simply a random clustering.

Even one hundred years of precise rainfall and temperature observations in the Pacific might not be sufficient to confirm a major tendency one way or the other. Moreover, many experts now suspect that El Niño events (and indeed many oceanic weather patterns) may alternate in form and severity on time-scales of decades to centuries.

Whatever the future may bring governments in terms of El Niño events, governments need never again be taken completely off guard by an El Niño or a La Niña. Due to the government's unprecedented foresight that climate scientists have made possible, the ocean's temperature shifts may not seem so unpredictable and diabolical, but are rather an ordinary part of life on the planet. "We have to realize that it is something natural that is going to happen again and again."

Finally, we conclude by saying that Bangladesh experiences the impacts of El Niño and La Niña episodes. For a better understanding and undertaking of appropriate mitigation measures against possible impacts of El Niño and La Niña events, more intensive studies need to be carried out in this area.

Annex 1

Forecasts Issued by the Storm Warning Centre (SWC) Dhaka

Forecast	Time of Issue
1 Bangladesh Daily Weather Summary (BDWS) Valid for 24 hours	0730 UTC Daily
(i) Farmer's Weather Bulletin Valid for 36 hours	0730 UTC Daily
(ii) Farmer's Weather Bulletin Valid for 24 hours	0100 UTC Daily
(iii) Weather Forecast for Dhaka and Neighboring areas	1200 UTC Daily
(iv) Special Weather Forecast for Dhaka and Neighboring areas	0000 UTC Daily

3. Inland River Port Warning

Valid up to	Time of Issue: Previous night	Time of Broadcast by Radio Bangladesh
0300 UTC	1500 UTC	1100 UTC
0700 UTC	2300 UTC	0000 UTC
1200 UTC	0430 UTC	0530 UTC
1900 UTC	1030 UTC	1130 UTC

4. (i) Sea Bulletin:

(ii) Compound

A	B	D	E	F	G
Aurora	Balloon	Dewdrop	Electron	Formula	Gasbag

Type	Based on Chart	Time of Issue	Time of Broadcast by Coastal Radio

Compound/Aurora	0300 UTC	0650 UTC	0850 UTC
Formula	0690/0900 UTC	0850 UTC	1250 UTC
Balloon	1250 UTC	1450 UTC	1650 UTC
Gas Bag	1500 UTC	1850 UTC	2050 UTC
Dew Drop	1800 UTC	2250 UTC	0050 UTC
Electron	2100/0000 UTC	0250 UTC	0450 UTC

(iii) Fleet forecast for Area C-90 — Time of Broadcast

(i) From 1000 UTC – 2200 UTC — 0610 UTC

(ii) From 2200 UTC – 1000 UTC — 1850 UTC

<u>Annex 2</u>

WARNING MESSAGE DISSEMINATION PLAN

WORLD WEATHER WATCH (WWW)

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U.N ENVIRONMENT PROGRAMME (UNEP) CLIMATE CHANGE MONITORING SYSTEM

GLOBAL TELECOMMUNICATION SYSTEM (GTS)

NATIONAL METEOROLOGICAL COMMUNICATION CENTER (NMCC)

STORM WARNING CENTER (SWC)
RADIO BANGLADESH
BANGLADESH TELEVISION (BTV)
RELIEF CONTROL AND DISASTER MANAGEMENT BUREAU
CYCLONE PREPAREDNESS PROGRAM (CPP)

COASTAL VOLUNTEERS
NEWSPAPERS

GENERAL MASS
BANGLADESH ARMY
BANGLADESH NAVY
BANGLADESH AIR FORCE
MARITIME AND RIVERINE PORTS
FLOOD FORECAST AND WARNING CENTER

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