MONITORING OF NATURAL DISASTERS USING REMOTE SENSING TECHNIQUES

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INTRODUCTION

Bangladesh currently ranks as the world's foremost disaster-prone country. The situation is aggravated, all the more by its being the most densely populated country in the world. Environmental disasters like tropical cyclones, storm surges, floods, norwesters, tornadoes and droughts ravage the country almost every year. During the last thirty eight years, the country was devastated by thirty eight severe cyclones of varying intensities. One of the severe ones in recent times was that of 29 April 1991, when material damage was to the tune of about 2.4 billion US dollars and human casualty of about 1,40,000 lives. On a previous occasion of a similar catastrophe in 1970, about half a million lives were lost. The Bangladesh flood of 1988 caused economic loss to the extent of about one billion dollar. And flooding in Bangladesh is a perennial problem. Every year Bangladesh is also affected by norwesters and tornadoes causing loss of lives and immense damage to property. Though Bangladesh is affected by floods frequently it is not spared from drought which occurs in Bangladesh occasionally causing extensive damage to crops. Bangladesh also lies in the seismic zone and hence comes under the risk of earthquakes. These disasters put the clock of our economic growth backwards. Unless we can adequately deal with them, our economic progress will remain a dream only.

The physical cause of these disasters are embodied in laws of science and hence proper scientific research is necessary to deal with them. The Role of Remote Sensing and Information Technology in the mitigtion of various natural disasters like Tropical Cyclones, Floods, Norwesters/Tornadoes, Earthquakes, Greenhouse effect etc. has been stressed in this paper.

TROPICAL CYCLONES

The tropics can be regarded as the region of the earth lying between 30^{o}N latitude and 30^{o}S latitude. All the tropical seas of the earth with the exception of the south Atlantic and east south Pacific give birth to deadly atmospheric phenomena known as tropical cyclones. On the average, 80 tropical cyclones are formed every year all over the globe. Bangladesh is a part of humid tropics, with the Himalayas in the north and the funnel shaped coast touching the Bay of Bengal in the south. This peculiar geography of Bangladesh causes not only the life giving monsoons but also catastrophic ravages of cyclones, norwesters, tornadoes and floods. The Bay of Bengal is an ideal breeding ground for tropical cyclones.

Though solar energy ultimately controls the terrestrial weather, the following environmental conditions have been found to be prerequisites for the development of cyclones **(i)** Absence of strong vertical wind shear of the horizontal wind near the cyclone centre and presence of strong vertical shear of opposite sign on either side of this system. The difference between the wind vectors between two vertical levels is known as the vertical wind shear **(ii)** Presence of low pressure region with cyclonic vorticity **(iii)** Warm ocean temperatures. A tropical storm does not form if the sea temperature is less than 27^{0}C. Such a high surface temperature is necessary to produce a steep lapse rate for

maintaining the vertical circulation in a cyclone. This condition is met throughout the year in regions of the Bay of Bengal where cyclones are formed. A cyclone can extend upto a height of 15 kms. All the low pressure systems may not develop into cyclones. Some just die out whereas others intensify into cyclones. A list of the major cyclones affecting Bangladesh is given in Table-I.

TABLE I

Cyclone affecting Bangladesh since 1960

Date	Max. wind speed in kms/hr	Storms surge ht. (in ft.)	Deaths
09 Oct. 1960	162	10	3,000
30 Oct. 1960	210	15-20	5,149
09 May 1961	146	8-10	11,466
30 May 1961	146	20-29	-
28 May 1963	203	14-17	11,520
11 April 1964	-	-	196
11 May 1965	162	12	19,279
31 May 1965	-	20-25	-
14 Dec. 1965	210	15-20	873
01 Oct. 1966	146	15-30	850
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	223	20-30	5,00,000
08 May 1971	-	8-14	-
30 Sep. 1971	-	8-14	-
06 Nov. 1971	-	8-18	-
18 Nov. 1973	-	8-13	-
09 Dec. 1973	122	5-15	183
15 Aug. 1974	97	5-22	-
28 Nov. 1974	162	7-16	a few
21 Oct. 1976	105	8-16	-
13 May 1977	122	-	-
10 Dec. 1981	97	06	02
15 Oct. 1983	97	-	-
09 Nov. 1983	122	-	-
03 June 1984	89	-	-
25 May 1985	154	10-15	11,069
29 Nov. 1988	162	5-10	2,000
29 April 1991	140	20-25	1,38,000
02 June 1991	100	06	-
02 May 1994	200	-	170
19 May 1997	225	15	126
26 Sept. 1997	150	10	70
20 May 1998	120	0.0	03

Determination of the Cyclone Track : The precise forces responsible for the motion of tropical cyclones is not understood clearly and hence determination of the path of the cyclone in advance is one of the most difficult tasks in meteorology.

Recently various statistical and numerical dynamical methods have also been introduced for the forecast of cyclone paths.

(1) Steering Principle was first applied by H. Mohn in 1870. Until 1950 forecasts of tropical cyclones were made by subjective methods based on synoptic maps and climatological behaviour. Following are some of the objective methods applied in modern times for cyclone forecasting. (2) Statistical methods relate predicted movement to one or more parameters in an empirical way. (3) Dynamical techniques, on the other hand make use of some forms of the equation of motion to predict numerically the motion of cyclone from an observed initial state of the atmosphere. (4) Hybrid model in which output parameters from a dynamical model are used in a statistical model. SPARRSO has installed a model named TYAN for predicting the track of a cyclone based on climatology of Bay of Bengal Cyclones for the last one hundred years. The model has shown promising results for the forecast of cyclone movement twenty four hour ahead of landfall. In Bangladesh, Meteorology Directorate is, responsible for the issue of cyclone warning.

Protection Against Cyclones : What can be done to protect ourselves from the cyclones ? A cyclone is a natural phenomenon like an earthquake or a volcanic eruption. We have to learn to live with it. We have to strengthen the cyclone warning system and adopt protective and relief measures to minimize their onslaught. SPARRSO monitors the tropical cyclones on an hourly basis with the help of the remote sensing equipment installed and passes the information to all concerned agencies including Bangladesh Meteorological Dept., Bangladesh Air Force, Honourable Prime Minister's Office, Ministry of Disaster and Relief and so on. With the help of the facilities at SPARRSO, we can determine the location, the intensity and the future course of motions of the cyclone. As a matter of fact no cyclone in the Bay of Bengal can escape the notice of the remote sensing equipment of SPARRSO. An integrated computerised method of Cyclone warning system needs to be developed.

Strongly built houses have to be constructed high above the sea level to serve as shelter places. People from the low lying areas in the coastal region can be evacuated into these shelters in the event of a cyclonic hit. Coastal embankments have to be made to protect life and property from the onslaught of storm surges. Plantation of trees along the coastal area can also diminish the fury of the storm surges.

FLOODS

The primary cause of flood in Bangladesh is rainfall in the catchment areas of the rivers of Bangladesh. Situated in the monsoon belt with the Himalayas in the north, Bangladesh falls in the region of very heavy rainfall. About 80 percent of the rainfall

occurs during the 5 month period from May to September. The annual rainfall varies from about 60 inches in the western part of the country to about 200 inches in the north eastern part. At Cherapunjee in Assam very near our Sylhet Border the average annual rainfall is about 500 inches which is the highest in the world. But the average rainfall in Bangladesh generates annually only 100 million acre feet of water whereas 1100 million acre feet of water comes from outside Bangladesh. Thus about 90 percent of the water carried by our river system, the Brahmaputra, the Ganges, the Meghna and other smaller rivers is brought from outside the country. These rivers carry water from an area of about 600,000 sq. miles of which only 7.5 percent lies in Bangladesh. Water enters in Bangladesh through three major channels but the discharge takes place through one major channel. The river system has evolved to carry the normal flow of water generated in the catchment area. Whenever the inflow of water is greater than the carrying capacity of the rivers (and this happens very often) flood results. The magnitude of the flood depends on the magnitude of excess water that is generated. A list of area flooded in different years is shown in Table II.

Table II

Area affected by flood in Bangladesh

Year	(thousand Sq. Km.)
1954	36.4
1955	49.9
1956	35.1
1960	28.2
1961	28.4
1962	36.9
1963	42.5
1964	30.7
1965	28.2
1966	33.0
1967	25.3
1968	36.3
1969	41.0
1970	42.0
1971	35.8
1972	20.5
1973	29.4
1974	52.0
1975	16.4
1976	27.9
1977	12.3
1978	10.8
1980	32.5
1982	3.1
1983	11.0
1984	27.9
1985	11.3
1986	3.1
1987	56.6
1988	81.8
1989	6.1
1990	3.5
1991	28.6
1992	2.0
1993	28.7
1994	0.42

Besides the primary cause, namely rainfall in the catchment area, there are other factors which may aggravate the floods. They are :

(1) Snow melting in the Himalayas.

(2) Hydrographic changes in the Brahmaputra basin.

(3) 2.4 billion tons of sediments carried by the river system of Bangladesh every year reduces the water carrying capacity of the rivers, which worsens the flood.

(4) Deforestation in the catchment area tends to aggravate the flood.

(5) Construction of unplanned roads, railways, barrages, embankments etc. also create obstacles to the flow of water and aggravate the flood.

Flood Forecasting and Warning : Bangladesh Govt. has taken up both the structural and non-structural measures of flood mitigation. In this respect regional and international cooperation has been sought. A Flood Action Plan with 26 components with the assistance of World Bank has been undertaken. Structural measures of flood control like storage reservoirs, embankments or levees, channel improvements and bypasses or floodways are costly and time consuming. For immediate benefit to public, non structural measures are accomplished at a much smaller cost and time. For flood forecasting a network of hydrological stations connected with telemetering gauges or by telecommunication or teleprinter links with the forecasting centre has been established by the Water Development Board. Available hydrological data consist of discharge, water level and rainfall records. Historical records of data have been analysed to prepare forecasting procedure. For major rivers, correlation of water levels or discharges between upstream and downstream stations are utilized in preparing forecasting procedure. For rivers with smaller catchments rainfall-runoff relation, flood routing, co-axial graphical correlation methods are used. Extensive modelling of flood in our river system is necessary for effective forecasting. The Flood Forecasting Cell of Bangladesh Water Development Board has considerably improved its facility for the issuance of flood forecasting. It uses the remote sensing data along with ground data. The methods need further automation. Remote Sensing data can be used to delineate the flood affected areas.

NORWESTERS AND TORNADOES

Though cyclones are the most devastating storms affecting Bangladesh, there are other kinds of storms which affect Bangladesh. Of these, mention may be made of Norwesters and Tornadoes which cause lot of destruction of lives and property.

Norwesters come mainly from the north westerly direction (and hence the name) and are land based. They are a very common phenomenon in Bangladesh during late Chaitra and Baishak months and are known in Bengali as Kalbaishaki.

Another kind of storm very similar to a tropical cyclone but is of much smaller dimensions and very destructive is known as a Tornado. A tornado is also a low pressure region where strong winds blow around a centre in an anticlockwise direction in the northern hemisphere and clockwise direction in the southern hemisphere. But unlike a cyclone a tornado develops on land. A cyclone lasts for days whereas a tornado lasts for a very short duration.

A tornado is formed because of the interaction of two air masses, one moist and warm air and the other dry and cold air resulting in extreme form of instability. Tornadoes often form a series and travel in almost parallel paths. The whole tornado moves at a speed of 25-30 miles an hour, whereas the maximum wind in a tornado could be 300 miles/hr.

Since the horizontal diameter of a tornado is so small and it forms so suddenly that it is difficult to recognise a tornado either in the surface weather map or in the satellite picture and hence forecasting of a tornado well ahead of occurrence becomes very difficult. We have observed that certain cloud features as obtained from satellite pictures and some other meteordogical parameters like the Showalter or Total Total Stability Index may indicate the occurrence of a tornado but again it is very difficult to pinpoint the place, time and severity of a tornado occurrence. Surface meteorological observations are taken usually at certain specified towns whereas a tornado can occur anywhere. A network of radars and frequent satellite observations may be very helpful in the early detection of tornadoes. Extensive research is needed on tornadoes to make any forecast possible.

DROUGHT

Though Bangladesh is a land of abundant rainfall, drought is very familiar to us. It is difficult to define the term drought precisely and hence any definition is rather subjective. It simply means lack of water and may be defined as lack of sufficient water to meet requirements. Thus drought can be of various kinds according to various requirements.

Drought History : The scourge of drought may be regarded as an integral part of the world climate. Wherever there is rainfall, there is drought also. Just like there is excess of rain causing floods, there is inadequate rain causing drought. Drought is by no means an isolated phenomenon or a purely local phenomenon. Sometimes drought occurs in large part of the globe and sometimes in many parts of the earth simultaneously. Excess rainfall may occur in some parts of the earth and drought may occur in another part. This may be due to the atmospheric teleconnections. Drought is again a recurrent phenomenon. There are records of severe droughts in history. In Bangladesh, drought of 1979 is the severest in living memory. In the seventeenth century, repeated drought and consequent crop failures occurred in Scotland which in the opinion of some forced the union of Scotland with England. In the 19th century repeated drought occurred in many

parts of USA and Canada . In the sixties, drought occurred in various parts of India and in the late sixties and early seventies, there was drought in the Sahel region of Africa.

Bangladesh Climate : Bangladesh is situated in the active monsoon regions of the world with an average rainfall of about 90" per year. But the rainfall distribution is not uniform throughout the year. Most of the rainfall i.e. about 80% occurs during the monsoon period i.e. June to October. About 5% rainfall occurs during November to February and about 15% rainfall occurs during March to May. This shows that the months November to February are very dry and may be regarded as permanent drought months. But this does not mean that Bangladesh has an arid climate because aridity in these four months is amply compensated by abundant rainfall during the rest of the year. However, the amount of rainfall varies considerably from year to year and from region to region. In some areas in the northwestern part of the country, the amount of annual average rainfall may be as low as 50" whereas in the north-eastern part, average annual rainfall may be as high as 200". There is a lot of variation of rainfall at different places from year to year. Specially during the premonsoon period, decrease of rainfall may seriously affect various crops. For example in 1979 rainfall during January to May was about one third of the normal though for the whole year, rainfall was only about 10% short of the normal. As people have adapted their crop to average climatic conditions, substantial decrease of rainfall may seriously affect the crops and other activities. Though a severe drought like the one that occurred in 1979 is not very frequent a study has shown that milder droughts occur in Bangladesh after an interval of 5-10 years. The years 1950, 1951, 1957, 1958, 1966, 1967, 1972 and 1979 were years of less rainfall in Bangladesh. We have witnessed severe drought in 1989 also. Some drought occurred during the post-monsoon season in 1997. Drought condition prevails in some part of the country almost every year for some of the time. Some of the droughts in Bangladesh seem to be related to El-Nino phenomenon.

Application of Remote Sensing Technology for Crop Monitoring :

REFLECTANCE CURVES

To know the spectral signature of various objects, it is necessary to find their reflectance characeristics. This is done by experiments both in the laboratory and in the field: Slide shows the reflectrance characteristics of a typical healthy leaf. We can easily see that it reflects strongly in the near infrared and absorption occurs in the yellow-red portion (chlorophyll absorption). If the plant is not healthy it will have a different reflectance characteristics and if we know it beforehand, this will help us in photo-interpretation.

The characteristics of various sensors used in different satellites are shown in Table-III and Table-IV.

TABLE - III
TIROS-N AVHRR CHANNEL CHARACTERISTICS

Channel	Resolution	Wavelength	Primary Use at Subpoint (micrometer)
1	1 km	0.55 - 0.90	Daytime cloud and surface mapping.
2	1 km	0.725 - 1.10	Surface water delineation/ vegetation mapping.
3	1 km	3.55 - 3.93	SST.
4	1 km	10.5 - 11.5	SST, day/night, cloud mapping.
5	1 km	11.5 - 12.5	SST.

TABLE - IV
LANDSAT-D EARTH-OBSERVING INSTRUMENTATION

THEMATIC MAPPER (TM) Micrometers		MULTISPECTRAL SCANNER SUBSYSTEM (MSS) Micrometers
Spectral Band 1	0.45 - 0.52	
Spectral Band 2	0.52 - 0.60	
Spectral Band 3	0.63 - 0.69	
Spectral Band 4	0.76 - 0.90	0.5 - 0.6
Spectral Band 5	1.55 - 1.76	0.6 - 0.7
Spectral Band 6	10.40 - 12.50	0.7 - 0.8
Spectral Band 7	2.08 - 2.35	0.8 - 1.1

AVHRR DATA

Neither channel 1 nor channel 2 of AVHRR sensor alone can effectively discriminate the vegetated areas. Healthy vegetation absorbs the radiation in channel 1 (visible spectrum) to a great extent whereas it highly reflects the radiation in channel 2 (infra-red) due to presence of chlorophyll. Thus a normalised Vegetation Index is calculated using the formula :

$$NVI = \frac{CH2 - CH1}{CH2 + CH1}$$

The country wide crop monitoring and crop estimation in Bangladesh is mainly performed using the NOAA-AVHRR data as received at the SPARRSO ground station on regular basis in addition to the usual application of these data in weather monitoring. NOAA-AVHRR data are received in five spectral channels of which first two are in the visible and NIR bands, and the rest are in the thermal bands. The spatial resolution of the data is 1.1 km at nadir. Each NOAA satellite provides two passes of data for a locality covering large area due to its large swath of about 2700 km every day and thus from three satellites (NOAA-12, 14 and 15) we can receive about 6 passes of data every day. As a result, there are fair amount of chances to get a cloud free pass for Bangladesh. Besides, the data of one week can be used to eliminate the cloudy areas and prepare a more or less cloud-free image. This procedure is called cloud screening. While the first two channels of the AVHRR data are used to calculate the Normalized Difference Vegetation Index (NDVI) which shows the green vegetation and leaf area, the rest of the three bands are used to estimate the temperature of the soil-surface and the crop canopy. The NDVI value ranges from 1 to +1; NDVI less than zero represents water, the low positive values represent bare soil and the high values of NDVI represent dense green vegetation coverage. The higher the NDVI, the more is the percent coverage of the green vegetation. Thus, in the temporal NDVI profile the vegetation index increases with the growth of the plants and attains the maximum value at its highest vegetative growth. Then, the NDVI decreases as the crops flower and mature.

MARINE STUDIES

It is possible to determine movement and concentration of fish population in rivers and oceans by means of satellite photography. In the oceans it is possible to determine such parameters as the surface conditions, wave heights, ocean currents and the temperature variations within the streams. A Fish industry stands to gain tremendously from the information obtained from spacecraft remote sensor.

A Project was taken up by SPARRSO using ADEOS OCTS data under the joint ESCAP/NASDA Project on Marine studies. Though the Project could not achieve its full objective due to early termination of ADEOS satellite, the available data along with

NOAA data have given immense information regarding sediment concentration, Sea Surface Temperature and Chlorophyll concentration in the Bay of Bengal.

MAPPING AND LAND USE

Another area which stands to gain immensely from satellite photographs is mapping. Of the present maps of the world, 70% are inadequate and 30% are obsolete. By normal convention, it takes a long time to produce a map and the data becomes obsolete before the map is available even in advanced countries. A satellite enable maps to be produced quickly with upto-date information on land formation, soil and water conditions. Already, major discrepancies have been found in many parts of the world between what the land mass was thought to be and what it proves to be, in detailed satellite photographs. This is particularly applicable in Bangladesh, where changes occur so frequently by erosion and change of river courses.

SPARRSO has produced several land use maps of the whole country using Landsat MSS and TM data.

Besides these, SPARRSO is constantly supplying satellite image products to various users throughout the year.

EARTHQUAKES

There is ample evidence from various geological studies that the earth's crust is in motion both horizontally and vertically. The modern theory of this aspect of the earth's surface is called plate tectonics.

Earthquakes occur in regions of the earth's crust which are undergoing deformation. As the region is deformed, energy is stored in the rock in the form of elastic strain. This continues until at some point the accumulated strain exceeds the strength of the rock. Then fracture or faulting occurs. Of the theories of earthquakes, perhaps the elastic rebound theory is the most successful one. This states that opposite sides of the fault rebound to a position of equilibrium and the energy is released in the form of heat, in the crushing of rock and in the vibration of elastic waves. The waves or vibrations which are generated at the moment of fracture produce the shaking which is experienced in earthquake.

The major earthquakes that have affected Bangladesh since the middle of the last century are the Cachar Earthquake of January 10, 1869, the Bengal Earthquake of July 14, 1885, the Great Earthquake of July 12, 1897, the Srimangal Earthquake of 8th July, 1918, the Dhubri Earthquake of July 3, 1930, the Bihar-Nepal Earthquake of January 15, 1934 and the Assam Earthquake of August 15, 1950. Of these, only the Bengal Earthquake of 1885 and the Srimangal Earthquake of 1918 had their epicentres in Bangladesh.

The damages caused by these shallow focus earthquakes however were restricted to narrow zones surrounding the epicentres. The greatest damage was caused by the 1897 earthquake. The tremors were felt all over the country and severe damages were caused in the northern parts of Sylhet and Mymensingh districts and in the eastern part of Rangpur district. The 1950 earthquake was also felt all over the country though no damage was reported.

Thus we see that Bangladesh is not entirely free from the menace of earthquakes. Specially the northern belt of greater Sylhet, Mymensingh and the eastern part of Rangpur Districts could be vulnerable. Bangladesh should develop adequate facilities for detection and study of earthquakes.

Satellite Remote Sensing can easily identify earth's fault zones where the earthquake mainly occurs. Very high resolution satellites are being used for the detection of tectonic movement of the earth.

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