USE OF REMOTE SENSING TECHNIQUES IN RISK MANAGEMENT IN AGRICULTURE

DR. A.M. CHOUDHURY
DIRECTOR
BANGLADESH SPACE RESEARCH AND REMOTE SENSING ORGANIZATION (SPARRSO)
AGARGAON, SHER-E-BANGLA NAGAR,
DHAKA - 1207

PRESENTED AT THE NATIONAL WORKSHOP ON " RISK MANAGEMENT IN BANGLADESH AGRICULTURE " HELD AT BARC, 24-27 AUGUST, 1991, DHAKA.

ABSTRACT

Bangladesh Space Research and Remote Sensing Organization (SPARRSO) has the capability to receive and analyse data from US NOAA and Japanese GMS satellites at six and one hourly

intervals every day in both visible and infra-red frequencies. Remote Sensing data obtained from these satellites can profitably be used in the study and warning of natural disasters like tropical cyclones, floods, norwesters and droughts. SPARRSO is also equipped with VAX-11/750 and Microvax computers for the analysis of these data. Data from other satellites like Landsat and SPOT acquired from abroad can also be analysed. The paper has been illustrated by cyclone imagery of 1991 and flood imagery of 1987 and 1988 received and analysed at SPARRSO. Risk analysis of the above mentioned natural disasters using remote sensing method has been discussed. The problem of drought has also been covered.

1.1 GENERAL INTRODUCTION

Modern Space and Remote Sensing Technology has openend a tremendous scope for the study and mitigation of the effects of natural disasters. There has been a proliferation of enormous amount of information due to the availavility of spaceborne platforms. A satellite passes over a place after fixed intervals, acquires the relevant data of the underlying portion of th earth and all these data can be acquired by suitable ground stations.

A disaster can be defined as any change in the environment of man that affects his works or his life in an unwanted fashion. In general, a disaster implies breaking down of a stable system.

In this paper, we shall be concerned with natural calamitieslike tropical cyclones, floods, norwesters, tornadoes and droughts which affect us very badly.

1.2 AVAILABLE SATELLITE DATA

SPARRSO receiving system can receive imagery from US NOAA and Japanese GMS satellites at six and three hourly intervals every day in both visible and infrared frequencies. They are used routinely for weather forecasts. The NOAA data can also be processed with the help of special software acquired for this purpose for mapping flooded areas if the sky is cloud free. The imagery cover the entire catchment area of Bangladesh and from the distribution of cloud cover, an estimate of the rainfall in the catchment area can be made, which can be used as input in flood forecasting model. There are high resolution satellites like French SPOT and US Landsat. But as data from these satellites are not available in Bangladesh on a real time basis and they cover a particular area after every twenty six or sixteen days, they have a limited use in flood forecasting. NOAA satellite data on the otherhand, though they have a resolution of 1 km (compared to 10 m for SPOT and 30 m for Landsat), because of their frequent coverage can be effectively used for flood monitoring and flood plain mapping.

The sensor characteristics of satellites are given below:

TABLE I
TIROS-N AVHRR CHANNEL CHARACTERISTICS

Channel	Resolution at Subpoint	Wavelength (micrometer)	Primary Use
1	1 km	0.55 - 0.90	Daytime cloud and surface mapping
2	1 km	0.725 - 1.10	Surface water delineation
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 II

LANDSAT-D EARTH-OBSERVING INSTRUMENTATION

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

The multispectral mode of SPOT satellite has three bands, 0.5 - 0.59 um, 0.61 - 0.67 um, 0.79 - 0.90 um, with a 20 m resolution. The panchromatic mode has a single band, 0.5 - 0.90 um, with a 10 m resolution.

TROPICAL CYCLONES

2.1 INTRODUCTION

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 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.

The term cyclone is derived from the Greek word "Kyklos" meaning coil of snakes. Satellite pictures of cyclones bear this out and the nomenclature seems very appropriate. Technically a cyclone is an area of low pressue where strong winds blow around a centre in anticlockwise direction in the northern hemisphere and clockwise direction in the southern hemisphere. Cyclones occurring in the tropical regions are called tropical cyclones and those occurring outside the tropical regions are called extratropical cyclones. Tropical cyclones are usually destructive and these are the ones which affect Bangladesh. Tropical storms are called Hurricanes in American continent, Typhoons in the Far East and Cyclones in the South Asian sub-continent. Actually they are the same phenomena, but are known by different names in different parts of the world. In the west, hurricanes are identified after girl's names such as Anna, Carol, Dorothy, Eve etc. A list of four sets of names in alphabetical order has been introduced. One set is used for each year and after every four years, the sets are repeated. Recently naming hurricanes after man's name has also started. In South Asian region no such nomenclature has been adopted.

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 catastropic ravages of cyclones, norwesters, tornadoes and floods. The Bay of Bengal is an ideal breeding ground for tropical cyclones.

The cyclones are orginally formed in the deep seas and hence their study has been very difficult. It is only with the advent of Space Age that weather satellites provide valuable information about them. Direct studies of cyclones with the help of aircraft reconnaissance are also being carried out by advanced countries. Only a beginning has been made towards the understanding of cyclones. A lot remains to be known still.

2.2 CAUSES OF FORMATION

Our planet earth receives all its energies from the sun. Hence it may be thought that the calamities like cyclones and blessings like monsoon rains owe their origin from the sun. But this is so only indirectly. Solar radiation is maximum at the earth's equator and minimum at the poles. Again different surfaces on the earth have got different capacities for absorption and emission of solar radiation. Thus different areas on earth are heated unequally. These variable factors give rise to low and high atmospheric pressure areas on the earth. It is

because of the existence of the low and high pressure areas that we get good or bad weather.

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 teperatures. A tropical storm does not form if the sea temperature is less than 27^0C. Such a high surface temperature is necessary to produce a steep lapse rate for maintaining the vertical circulation in a cyclone.

The Bay of Bengal cyclones are formed mostly near the Andamans. They usually occur at latitudes greater than 5^ON. It is thought that Inter-Tropical Convergence Zone (ITCZ) has got to do something with their formation. The ITCZ is the region where winds from the two hemispheres meet and is situated near the equator, but its position varies with season. Conditional Instability of the Second Kind (CISK) was suggested as a mechanism for the formation of tropical cyclones. However, other mechanisms have also been suggested. A cyclone derives its spinning motion from the rotational motion of the earth called the Coriolis Force. This force is virtually zero at the equator. Hence, cyclones do not usually form at the equator. They are formed slightly north or south of the equator to get the necessary spin. It is probable that the easterly waves also play some part in the formation of cyclones.

As soon as a low pressure area is formed, air from all directions converges towards this area. This phenomenon is called low level convergence. It causes the air to spin faster and the air spirals inwards and upwards at an increasing rate causing heavy rain and thunderstorm. The air is also made very moist by rapid evaporation from the warm ocean. In the low pressure region itself, air rapidly moves upwards and diverges. This is called high level divergence. Thus, there must exist some mechanism for the quick removal of the ascending air. The latent heat released by the condensation of water vapour warms the air and keeps it unstable. This latent heat is also thought to supply the necessary energy of the cyclone. The total energy involved in a moderate cyclone may be equal to that in several thousand atom bombs of megaton strength.

A cyclone can extend upto a height of 8-9 miles. Some suggest that a triggering mechanism may exist in the upper atmosphere for the formation of cyclones. All the depressions may not develop into cyclones. Some just die out whereas others intensify into cyclones.

TABLE III
CYCLONES AFFECTING BANGLADESH SINCE 1960

Date	Max. wind speed in miles/hr	Storms surge ht. (in ft.)	Deaths
09 Oct. 1960	100	10	3,000
30 Oct. 1960	130	15-20	5,149
09 May 1961	90	8-10	11,466
30 May 1961	90	20-29	-
28 May 1963	125	14-17	11,520
11 Apl. 1964	-	-	196
11 May 1965	100	12	19,279
31 May 1965	-	20-25	-
14 Dec. 1965	130	15-20	873
01 Oct. 1966	90	15-30	850
11 Oct. 1967	-	6-28	-
24 Oct. 1967	-	5-25	-
10 May 1968	-	9-15	-
17 Apl. 1969	-	-	75
10 Oct. 1969	-	8-24	-
07 May 1970	-	10-16	-
23 Oct. 1970	-	-	300
12 Nov. 1970	140	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	75	5-15	183
15 Aug. 1974	60	5-22	-
28 Nov. 1974	100	7-16	a few
21 Oct. 1976	65	8-16	-
13 May 1977	75	-	-
10 Dec. 1981	60	6	02
15 Oct. 1983	60	-	-
09 Nov. 1983	75	-	-
03 June 1984	55	-	-
25 May 1985	95	10-15	11,069
29 Nov. 1988	100	5-10	2,000
29 Apr. 1991	140	20-25	1,38,000

2.3 CLASSIFICATION

Cyclones in the South Asian sub-continent are presently classified according to their intensity and the following nomenclature is in use :

Depression : Winds upto 38 miles/hr.

Cyclonic Storm : Winds from 39-54 miles/hr.

Severe Cyclonic Storm : Winds from 55-73 miles/hr.

Severe Cyclonic Storm of Hurricane Intensity : Winds above 73 miles/hr.

It has been observed from satellite pictures that a mature cyclone has got a well organized cloud pattern. It is possible to deduce the wind speeds in cyclones from the size and degree of organization of the cloud pattern.

Refined classification from categories T1 to T8 called T numbers in a continuous scale has been made. Central pressure of the cylone, corresponding T number and wind speeds in the Pacific, the Atlantic and the Bay of Bengal are shown in Table IV.

TABLE IV

COMPARISON OF MEAN SEA LEVEL PRESSURE CORRESPONDING TO DIFFERENT MAXIMUM WIND SPEEDS(MWS) AMONG ATLANTIC, PACIFIC AND BAY OF BENGAL

T Number	MWS (Km/hr)	MSLP (mb)	MSLP (mb)	MSLP (mb)

		(Atlantic)	(Pacific)	(Bay of Bengal)
1.5	46	1010	1004	1000
2	56	1007	1001	998
2.5	65	1003	997	997
3	74	998	992	995
3.5	93	993	987	992
4	112	988	982	989
4.5	134	979	973	983
5	158	970	964	975
5.5	180	960	954	965
6	205	948	942	949
6.5	227	934	928	937

2.4 FEATURES

The most individual feature of a cyclone is its `eye' usually found in severe cyclones. The eye can be seen in the satellite pictures clearly in the case of storong cyclones. The eye is small and almost circular, conincides with the area of lowest pressure having a diameter ranging from 5-30 miles. The eye is warmer than the rest of the storm. The more violent is the storm, the warmer is the eye. The winds are very light in the eye, usually not more than 15-20 miles/hr. and rain is practically absent. In contrast, the strongest wind and the heaviest rain occurs just outsied this central eye.

The wind speed gradually diminishes as one goes away from the region of strongest wind. The main core of the cyclone is circular or nearly circular having a diameter ranging from 100-500 miles. The main cyclone is often accompanied by a long tail having more than one band, the whole thing making a spiral structure, and looking like an inverted comma, The tail may extend upto a few hundred miles. The tail usually crosses the land well before the main core of the cyclone and as a result the sky is overcast with cloud and rain often sets in before the onset of a cyclone. Such symptoms can serve as a warning for the possible approach of a cyclone.

2.5 THE TRACK OF THE CYCLONE AND STORM SURGES

The cyclones in their initial stages move at a rate of 5-10 miles/hr. In their final stages they may move at a rate of 15-20 miles/hr. or even upto 30 miles/hr. Cyclones formed in the Bay of Bengal usually move northwesterly in the begining and then curve eastwards. But this pattern is not uniformly followed as can be seen from the tracks of various cyclones. The cyclone usually decays after crossing the land. Cyclones are accompanied by heavy rains and swell of the sea called storm surges. If the cyclone occurs during high tide then the storm surge is reinforced

considerably. The maximum value of storm surge can be as high as 40 ft. in the Bay of Bengal. Most of the damage is done by the deadly wall of water associated with cyclones and inhabitants are met with watery graves. The storm surges associated with various cyclones that struck Bangladesh since 1960 are shown in Table III. A model estimation of maximum storm surge heights corresponding to various wind speeds as prepared by SPARRSO is shown in the Table V.

TABLE V

RELATIONSHIP BETWEEN PRESSURE DROP, WIND SPEED AND SURGE HEIGHT

Pressure Drop (mb.)	Wind Speed (miles/hr)	Surge Height in ft. (Maximum value)
10	40	3.87
12	47	5.71
14	54	7.48
16	60	9.18
18	67	10.81
20	67	10.81
22	77	13.88
24	82	15.31
26	87	16.68
28	91	17.98
30	94	19.21
32	98	20.48
34	101	21.48
36	104	22.51
38	106	23.48
40	109	24.38
42	111	25.21
44	113	25.98
46	115	26.68
48	117	27.31
50	119	27.88

Contd...

52	121	28.38
54	123	28.81
56	125	29.18
60	129	29.70
62	131	29.88
64	133	29.98
66	136	30.01

2.6 DETERMINATION OF THE CYCLONE TRACK

The precise forces responsible for the motion of troopical 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.

The classical methods for forecasting cyclone tracks are judiciaous consideration of climatology of cyclones, persistence of motion and some steering current of the upper atmosphere. Tropical cyclones often show different preferred paths in different times of the year. Hence, climatology of cyclones provides some good guess for considerations to base the initial forecast. However, as there are large number of exceptions, forecst based on climatology alone cannot be entirely relied upon.

Persistence of motion assumes that integrated effect of all forces which have caused the tropical cyclone to move during some past period will continue in the future period. However, the technique fails when recurvature takes place and some cyclones may depict recurvature more than once.

In cyclone forecasting, it is often assumed that cyclone follows the direction of upper atmosphere current at 200 or 300 mb. SPARRSO in collaboration with Dhaka University has undertaken an investigation into the problem and it has been found that there seems to be a steering current for every cyclone, but the level differs from cyclone to cyclone and there does not seem to be any relation with intensity of the cyclone. Moreover, the upper atmospheric current is as variable as the track of the cyclone and hence it is difficult to find out the exact steering current.

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

2.7 ROLE OF WEATHER SATELLITES IN CYCLONE WARNING

Weather in a global phenomenon and to know the initial state of the weather at a particular time, accurate observations on worldwide scale are needed.

The distribution of surface observations is heavily biased towards well populated land regions. Commercial shipping does provide some observations over the oceans. But as the ships avoid the cyclones, most vital data on cyclones are left out. High up the atmosphere, balloons can rise upto a maximum height of 20 miles only. Thus the vast expanse of the atmosphere and the

oceans remained unexplored before the space age. With the advent of the space age, rockets can gather data at different heights of the stmosphere and satellites can survey the earth's weather from a point well above the earth's surface. The advantages of space meteorology over the conventional methods are as follows:

(1) Spatial continuity: The observations are horizontally continuous, this eliminates interpolation and thus the ambiguity often present in synoptic charts.

(2) Provides information on a synoptic scale with virtually no time lag.

(3) Visual Integration: Permits integrated visualization of weather systyms in a way readily acceptable to the numan mind.

(4) Independence of Communication System: Provides large scale weather information even if normal system of communications have broken down.

Thus the superior quality of the Space Meteorology is unquestionable. But this does not make the traditinal synoptic meteorology obsolete. It rather supplements the old system. Improvement and innovations of the old system are continually taking place.

Bangladesh does not have either rocket or satellie facilities of its own, but with the help of ground stations, we can receive weather pictures from weather satellites launched by advanced countries.

An APT (Automatic Picture Transmission) Ground Station for the reception of imgery from weather satellites was established in 1968 in Bangladesh. Initially it was installed by former SUPARCO in the Atomic Energy Centre Building, Dhaka. Recently SPARRSO has established advanced receiving and analysing equipment including VAX computers, printers and International Imaging System monitors for the reception and analysis of satellite data under its Agroclimatic/Environmental Monitoring Project. A Data Collection Platform (Ocean Buoy) was also installed in the Bay of Bengal for recording and transmission of real time data on sea level, wind velocity, atmospheric pressue, ocean current, sea surface temperature and salinity. These data were transmitted to SPARRSO Ground Station via orbiting NOAA satellites.

Facilities also exist for extracting information on the upper atmosphere regarding water vapour content, temperature, pressure etc. as a function of altitude from the Tiros Operational Vertical Sounder (TOVS) data of NOAA satellites.

With the help of these equipment both low and high resolution data from US NOAA-10 and NOAA-11 and Japasnese GMS-3 satellites

are received. The GMS satellites transmit data normally after every three hours. However, as Bangladesh comes at the corner of the picture, resolution of GMS for Bangladesh is not so good. NOAA-10 and NOAA-11 satellite transmits good quality low and high resolution data twice daily. An automatic grid i.e. latitude longitude and national boundaries can be fitted in the picture with the help of the present equipment. Because of these equipment, no cyclone in the Bay of Bengal can escape our notice. We can detect the cyclones, analyse their intensity, determine their position and track their motion. From the degree of organization of the cloud patterns and their sizes, we can deduce the maximum wind speeds in cyclones.

2.8 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. Experiments conducted in the United States to reduce the intensity of cyclones by cloud seeding have not provided any conclusive results. We have to strengthen the cyclone warning system and adopt protective and relief measures to minimize onslaught of cyclones. 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 surge.

Besides taking up an elaborate programme for the construction of coastal shelters, embankment and afforestation, Bangladesh to-day has got a very comprehensive and elaborate Cyclone Preparedness Programme operated by the Bangladesh Red Cross Society. It has a membership of about 20,000 devoted volunteers spread over 2,043 wards of 195 Unions of the coastal belt of Bangladesh. In each ward the trained volunteers do the needful in the event of a cyclone. Each ward is provided with a transistor radio, a megaphonecum-siren, a signal torch light and first aid kits. Almost each U.Z. is provided with a wireless set which keeps direct communication with Dhaka. The Red-Cross volunteers are responsible for the following :

(1) Spreading warnings against approching cyclones reported by radio, surveying damages caused by cyclones and reproting them to the Union Headquarters.

(2) The arrangement of shelters for people, possibly also for cattle and for security of other property.

(3) The rescue of survivours still in danger.

(3) First-aid to the wounded and post-cyclone sanitary

measures.

(5) Distribution of food and clothing to the needy.

The Red-Cross volunteers move into action in the event of a cyclone disaster. The whole Government machinary including the Army, the Navy, the Air Force and the relevant agencies are put into operation in the event of a cyclone disaster. The relief operations are supervised by the Supreme Command Headquarters and the decision regarding the evacuation of personnel are taken by the highest authority of the Government. There is a standing order for cyclones which lay down actions by all concerned during the various stages of the disaster.

2.9 RISK ASSESSMENT FOR TROPICAL CYCLONES

As it is very difficult to predict the area affected by cyclones much ahead in time, this poses problems for taking action measures by the farmers. However, as soon as cyclones are formed in the Bay of Bengal, the farmers should take all the precautionary measures, such as harvesting the rice that is ready for harvesting.

The cyclone warning should include risk assessment for the areas to be affected by cyclone. For example, the possible wind speed and storm surge heights at each location should be specified. The farmers in addition to saving their lives should put their valuables including agricultural products under the earth in safe containers so that after the passage of the storm surge, the containers could be recovered. The livestock could also be taken at elevated places.

FLOODS

3.1 BANGLADESH RIVER SYSTEM

The Ganges originates near the Gangotri Glacier of the Himalayas with an elevation of over 23,000 ft and has a length of about 1600 miles. It receives the flow of a number of major tributaries namely Gogra, Gandak and Kosi originating in Nepal and Tibet. Another tributory of the Ganges, the Mohananda which flows through Bangladesh originates in India. The catchment area of the Ganges is about 3,50,000 square miles spread over four countries namely China, Nepal, India and Bangladesh.

The Brahmaputra originates in Tibet and has a length of about 1800 miles upto its confluence with Ganges. It flows under the name of Tsangpo in Tibet north of the Himalayan range for a distance of 700 miles. It turns south under the name of the Dihang and is joind by its main tributories the Dibang, the Lohit and the Dihing. It then flows westwards down the Assam valley as Brahmaputra, thereafter it enters Bangladesh (where the main flow is known as Jamuna) and is joind by Dharala at Kurigram and Tista at Chilmari. The catchment area of the Brahmaputra is about 2,24,000 square miles and is spread over China, India, Bhutan and Bangladesh.

The Meghna is formed by the confluence of the Surma and Kushiara together with other streams from hills in the northeast. The Surma is fed mainly by the tributories from Jainta Hills while Kushiara is fed by tributories from Tripura hills. The Meghna system is about 500 miles long of which about 260 miles lies in Bangladesh and the rest in India. The total catchment area of the Meghna above Bhairab Bazar is about 25,000 square miles of which about 32% lies in Bangladesh.

3.2 STATISTICS ON BANGLADESH FLOOD

Bangladesh is very much affected by flood.
This is borne out from the following Table :

TABLE VI

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	36.9
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

Source : BWDB

3.3 CAUSES OF FLOOD IN BANGLADESH

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 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.

It must be remembered that flood in Bangladesh is caused by rainfall in the catchment areas of the river systems of Bangladesh, 92.5 percent of which lies outside it, namely in India, Nepal, Bhutan and Tibet (China). Thus though there may not be much rainfall locally, there may be heavy rainfall in the catchment area causing flood. Of course, if there is rainfall in Bangladesh as well, flood will worsen. In these days, with the help of weather satellite imagery, rainfall in the whole catchment area can be monitored. Again it is not the rainfall for the whole year that is responsible for flood. The rainfall for the whole month or the year may be normal but if a whole month's rainfall in the whole catchment area occurs over a matter of few days and if the soil is already saturated because of previous rainfall, severe flooding may result. It is difficult to imagine the nature of rainfall in hilly areas where most of the catchment areas of Bangladesh rivers lie. Whereas the average annual rainfall at Dhaka is about 80 inches, that at Cherapunjee is 500 inches and the maximum rainfall at Cherapunjee is 900 inches a year. That means in hilly areas rainfall could be as much as ten times that in the plains of Bangladesh.

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 can also contribute towards flood. However, maximum flooding occurs in Bangladesh during August-September whereas maximum snow melt occurs probably during May-June and as the snow melting process is normally quite slow, this alone may not be a great factor in causing flood in Bangladesh. However, as rainfall itself accelerates the process of snow melt, the contribution of snow-melting as a factor in flood may not be entirely negligible. More research needs to be done in this field.

(2) It is understood that considerable hydrographic changes have taken place in the region specially in the Brahmaputra basin as a result of 1950 earthquake in Assam. This has resulted in the rise of the bed of Brahmaputra river in the upper reaches, thus reducing the carrying capacity of the river. This may be one of the reasons for increase of flood frequency in Bangladesh after 1950.

(3) It is estimated that about 2.4 billion tons of sediments are carried by the river system of Bangladesh every year and part of this sediment is deposited in river beds. This reduces the water carrying capacity of

the rivers, which worsens the flood. As a matter of fact many of the past active rivers have ceased to be active in the dry season.

(4) The catchment areas of the rivers of Bangladesh are being denuded of forests at an alarming rate. The soil in the catchment area which was covered by forests previously is becoming bare. Forest covered soil absorbs part of the rain water but bare soil absorbs less water and consequently run off is more. Thus deforestation in the catchment area tends to aggravate the flood.

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

(6) Because of the southwest monsoon wind, the mean sea level rises by about two feet during summer. If there are depressions in the Bay of Bengal and the magnitude of the wind is more, the sea level may rise further creating obstacles to the river flow thus aggravating the flood.

(7) High tide occurs during new and full moon twice every month. If the flood peak occurs during high tide time, aggravation of the flood may result. Moreover, if the moon is at perigee that is at the nearest distance from the earth, tide could be more and flood could further worsen.

3.4 FLOOD OF 1988

August-September Flood of 1988 is perhaps the worst flood in our recorded history. It came within a year of another record flood of 1987. It looked rather astonishing that when there was not much rain in the country, all the major rivers were swelling and swelling submerging more and more areas under water including about two third area of the capital. However, it is to be noted that the water which passes through Bangladesh comes from an area 92.5 percent of which lies outside Bangladesh. Therefore we must inquire what was happening in that area. It must also be noted that the month of August is the height of the monsoon season in the region when soil becomes saturated because of previous rainfall and flooding occurs in one part or the other during this time. Even in a non-flood year, rivers are full to the brim during this time. Moderate amount of rainfall in the catchment area at this time is sufficient to cause considerable flooding.

If we look at the satellite imageries taken by NOAA-9 and NOAA-10 weather satellites and processed at SPARRSO, we notice that from 20 August to 01 September, 1988 most of the catchment area of the river Brahmaputra and at times of the Ganges and

Meghna as well was covered by cumulonimbus clouds indicating heavy rainfall. If this sort of cloud occurs at a place for 2/3 days, this is sufficient to cause a moderate flood. Thus one can explain the degree of flooding that could result as a consequence of heavy rain for continuous 12/13 days. Even after this period,

rainfall was not totally absent. There was sporadic rainfall of moderate to heavy intensity at places thus prolonging the flood until the third week of September.

There was report in the press that on August 23, at Dibrugarh in upper Assam of India the Brahmaputra was flowing 1.4 metre above danger mark, an all time high record. The largest Bailey bridge in Asia situated at Arunachal Pradesh of India having a length of 940 feet collapsed. Oil production in Assam at many places was closed down as a result of flooding and their tea industry suffered badly. All schools and many Government Offices in Assam were closed down as a result of flooding.

It takes a few days for the flood water in upper Assam to travel to lower Assam and thereafter in Bangladesh. By the time flood water from upper Assam has reached lower Assam, there was heavy rainfall continuously for several days in lower Assam and in northern Bangladesh as can be noticed in the satellite pictures. Thus water in the Brahmaputra continued to swell and swell and at Bahadurabad flood peaked on 29 August, 1988 making an all time record. It may be mentioned that on 28 August there was full moon and the moon was at perigee (nearest distance to earth) as well and consequently the ocean tide was also very high around this time. In addition, rainfall in the catchment areas of the Ganges and the Meghna was also high and the three major rivers reached peak levels almost simultaneously fulfilling all the conditions of a catostrophic flood. This is shown in the river system hydrographs.

It may be mentioned that 1988 flood was not caused by monsoon depressions in the Bay of Bengal and so there was no high wind in the Bay of Bengal and hence no abnormal rising of the sea level due to wind was expected at this time. There is a theory that the sea-level all over the globe is rising due to the temperature increase by green-house effect caused by carbon dioxide and other gases in the atmosphere. This is a gradual effect and is expected to be significant during the next fifty years or so. Hence the greenhouse effect for 1988 flood may not be directly relevant. But its effect in the changes of global climate causing severe positive rainfall anomalies needs to be investigated.

3.5 FLOOD OF 1987

1987 flood of Bangladesh was also a very catastrophic flood of this century though its destructive capacity was less than that of 1988. The character of the two floods are different. The year 1987 was a year of monsoon failure for most of South Asian sub-continent. The Bay of Bengal monsoon depressions which usually travel northwestwards extending upto western India changed their course drastically in 1987. Almost all the depressions with the exception of one or two travelled northwards causing rainfall in Bangladesh, Assam, Bihar, West Bengal, Bhutan and Nepal. Consequently these areas were flooded and Bangladesh being the lower riparian country got the most of it. Flood in 1987 was the result of heavy rainfall both in Bangladesh and adjoining areas and in some areas of Bangladesh rainfall during the months of July and August were two or three times the normal value. On the other hand, the catastrophic flood of Bangladesh in 1988 was caused mostly by rainfall in the catchment area lying outside Bangladesh though in some northern areas of Bangladesh there was excessive rainfall during the later part of August. Another significant feature of this year's flood was that rainfall in the catchment area was not caused by moving depressions which is usually the case but due to standing low pressures formed in the foothills of the Himalays adjoining Bangladesh. Thus climatic variability plays a dominant role in the creation of flood.

3.6 FLOODS OF DIFFERENT YEARS COMPARED

Highest river levels for some of the great floods of Bangladesh for the years 1954/55, 1974, 1987 and 1988 for 9 stations are examined. This shows that for 5 stations namely Bahadurabad, Serajganj, Goalando, Dhaka and Narayanganj the river levels for 1988 had been record high for all time. For three stations it was higher than 1987 but not all time high and only for one station namely Rajshahi, it did not exceed the 1987 value. The severity of 1988 flood is shown in the comparative hydrographs of Bahadurabad, Hardings Bridge and Bhairab Bazar for 1974, 1984, 1987 and 1988.

TABLE VII
Highest River Levels (in feet)

Stations	1954/55	1974	1987	1988	Remarks
Bahadurabad	65.5 (1954) 65.95(1955)	66.42	64.55	67.96	All time high
Serajganj	45.3 (1954)	46.67	47.79	49.6	All time high
Goalando	31.48	31.22	32.24		All time high

Rajshahi	61.2(1954)	60.81	63.82	62.32	Not higher than 1987
Hardinge Bridge	47.40(1954)	47.17	48.54	48.77	Higher than 1987
Bhairab Bazar	25.00(1954)	25.00	22.66	24.83	Higher than 1987
Chandpur (1955)	17.54(H) 14.16(L)	17.10(H) 15.94(L)	15.42(H)	16.86(H)	Higher than 1987
Dhaka	23.25(1955)	21.70	21.78	24.86	All time high
Narayanganj	20.45	20.45	19.81	21.98	All time high

3.7 FLOOD AREA MONITORING BY SATELLITES

If the sky is cloud free, NOAA satellite imagery can be processed with computer to delineate the flooded areas. This has been done for August 31, September 01, September 10, September 15, September 18 and September 24 for the year 1988. It has been estimated that about 30,000 sq miles of Bangladesh was flooded in 1988.

3.8 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 Plan with 26 components with the assistance of World Bank is being implemented. 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 newtwork 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 downstrem stations are utilized in preparing forecasting procedure. For rivers with smaller catchments rainfall-runoff relation, flood routing, co-axil graphical correlation methods are used. It is possible to estimate with reasonable accuracy the time of arrival of flood peak and its height based on past experience and sequence of water levels at

upstream stations. It takes about two days for flood wave to travel from Bahadurabad to Goalundo and a day to reach Sirajganj. It takes about 24 hours for the flood to travel from Nunkhawa in Assam to Bahadurabad. So a three days lead time is available for flood at Goalando based on data at Nunkhawa. Similarly flood wave takes two days to reach Bahadurabad from Gauhati and travel time from Patna to Hardinge Bridge is about three days. At present under the Indo-Bangladesh Joint River Commission agreement, the stations from which water level data are received from India are Farakka, Goalpara, Dhubri, Domohani and Shilchar. Negotiations are going on for getting data from three more stations namely Omarpur, Kailasar and Khowai.

3.9 SPARRSO'S ROLE IN FLOOD PREPAREDNESS AND FORECASTING

A complete control of floods in Bangladesh seems to be a long way off. Until that is done it looks that we have to live with it. For that, reliable prediction of flood is necessary. Currently SPARRSO monitors the clouds in the catchment area several times a day regularly. The clouds could be translated into rainfall in different areas of the catchment. Mathematical models exist for the catchment rainfall to be included as input in the model. The output of the model will give flood heights in the major rivers in subsequent times. This will increase the lead time for flood forecasting and preparedness. Emergency measures like evacuation and relief could be carried out more effectively. The model could incorporate the height contours of different areas of the country so that if we know the river level at a particular point, the areas that go under inundation could be determined. Flood images of NOAA satellite also shows which areas have been inundated so that the areas which need relief measures could be determined from satellite imagery. Flood is mainly a climatic phenomenon and it is not possible to predict accurately excessive rainfall even a month not to speak of a year in advance. However, with the incorporation of satellite data in the flood prediction model, it would be possible to increase the prediction lead time by several days and this should enable the concerned agencies to carry out necessary preparedness measures. In addition to the current method of forecasting only the river level changes, in order that the flood forecasts become more meaningful, it is also necessary to forecast the area inundated and the depth of inundation. These will be attempted under the Flood Action Plan using the Geographic Information System (GIS) of SPARRSO.

3.10 ESTIMATION OF CROP DAMAGE

With the versatile radiometer on board the NOAA satellite, it is also possible to prepare what is called the Vegetation Index showing the health of crops. This is being done on an experimental basis for the last few years. SPARRSO estimated the Aman crop damage due to 1987 and 1988 flood. Analysis of NOAA-10 image for 24 September, 1988 shows that in heavily flooded areas like Dhaka, Faridpur, Brahmanbaria and Habiganj regions damage to

crop was very extensive. However, Crop condition in the North-Western Bangladesh was very good.

Here again if the area flooded and the depth of flooding should be forecast in flood forecasting bulletins so that people can take some protective measures with regard to their valuables.

4. 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.

Norwesters come mainly from the north westerly direction (and hence the name) and are land based. They are very common phenomena in Bangladesh during late Chaitra and Baishak months and are known in Bengali as Kalbaishaki. From the Meteorological Department sources their monthly distribution at Dhaka is as follows :

Month	March	April	May	June
Average Days of occurence	5.6	8	10	9.3

Norwesters are characterised by strong surface winds upto a maximum of 70-80 miles an hour accompanied by heavy rain, thunderstorm and occasional hail. Norwesters originate in the encounter between westerly low pressure cells accompanied with the dry and cold continental air with the tropical hot and moist maritime air form the south at a height of some 1-2 miles up in the atmosphere. Norwesters cause widespred damage throughout Bangladesh every year.

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.

The horizontal diameter of a tornado varies from a few feet upto a maximum of one mile. The pressure at the centre of a tornado is much lower than the surroundings and the air in the centre rises rapidly. Tornadoes usually have a funnel shaped cloud. The funnel may rise and descend and twist in a rather violent fashion. Tornadoes are usually acccompanied by heavy rain and thunderstorm. Because of the excessively strong pressure gradients build up around the low-pressure centre, very strong

winds develop in a tornado. Peak wind velocities are estimated from the damages and destruction left by a tornado, as no recorder can survive the onslaught of a tornado. From the damages, it is estimated that the wind velocities oftern exceed 200 miles/hr. and may be upto 500 miles/hr. In addition to the devastation caused by strong winds, much damage to dwellings result from the pressure change which accompanies the passage of a tornado. Buildings practically explode as a result of a tornado and tornado striken city or village looks as if raided by a bomb.

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 paralles paths. The whole tornado moves at a speed of 25-30 miles an hour.

Most tornado paths are less than 1000 ft. wide and not usually more than 25 miles long. It often skips and jumps and thus it may not causes descruction all along its path.

Tornadoes in Bangladesh occur mostly during March-June and in the afternoon. The weather is very humid and oppressive before the occurrence of a tornado. There is no adequate statistics of Tornadoes available in Bangladesh. But lately we have seen that every year different parts of Bangladesh are struck by a large number of tornadoes causing a lot of damage to life and property. Among the worst tornadoes of Bangladesh are the devastating Demra tornado of 14 April 1969, Manikganj tornado of 17 April 1973, Faridpur (affecting Vaderganj, Madaripur etc.) tornado of 10 April 1976, tonadoes affecting Faridpur and Keshorganj occuring on 31 March and April 1, 1977 and the tornado of 26 April, 1989 occuring at Shaturia area of Manikganj. Damages due to these tornadoes had been considerable.

Since the horizontal diameter of a tornado is so small and it forms so suddently that it is difficult to recognise a tornado either in the surface weather map or in the satellite picture and heance forecasting of a tornado well ahead of occurrence becomes very difficult. We have observed that certain cloud features 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 oobserations are taken usually at certain specified towns whereas a tornado can occur anywhere. A network of radars may be very helpful in the early detection of tornadoes. Placement of a geostationary satellite with frequent transmission say at an interval of every half hour could be helpful for the study and forecast of tornadoes. Aircraft reconnaissance also could be helpful in this respect. Though we have seen the tornadoes occur mostly during norwester season, they can occur during other season as well. It has been found that cyclones are often accompanied by tornadoes. There may be many tornado cells in a cyclone. Tornadoes which struck several places in Bangladesh on

30 September, 1974 were probably the effects of a cylone which crossed Orissa coast on 28 September, 1974 and then travelled towards East and Northern Bengal. Besides Bangladesh, tornadoes also occur in United States and Australia. There is a record of some 898 tornadoes occurring in United States in the single year 1965.

During the norwesters season, flash floods occur occasionally causing huge loss to agriculture. If the lead time for flooding of forecast be increased then also people could take some protective measures.

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.

5.1 DRY LAND

The dry land of the world (arid and semi-arid) are constituted as follows :

Continent	Area, Million sq. km	%Total
Africa	18	64
Asia	16	39
Australia	6	81
North America	4	17
South America	3	16
Europe	1	1

An area is called arid if the rainfall there is less than 10" a year and semi-arid if it lies between 20" and 10". Again this may vary from place to place and is dependent on temperature.

However, a distinction must be made with regard to aridity and drought. Arid regions are more or less permanent drought regions where rainfall varies from time to time. Drought however,

may occur occasonally in regions of abundant rainfall.**5.2 DROUGHT HISTORY**

The scourage 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 menas 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 similtaneously. Excess rainfall may occur in some parts of the earth and drought may occur in another part. This may be due to the atmoshereic 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 occured 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 occured in various parts of India and in the late sixties and early seventies, there was drought in the Sahel region of Africa. In seventies drought also occurred in USSR.

5.3 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 thorughout the year. Most of the rainfall i.e. about 77% occurs during the monsoon period i.e. June to October. About 8% rainfall occurs during November to February and about 20% 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 cliamte because aridity in these four months is amply compaensated 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 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. Drought was persistaent throughout

the country until late April and in some parts until mid May. Again during the monsoon months, drought prevailed in some parts of the country. We see that drought sometimes occurs during two consecutive years.

5.4 CAUSES

Though droughts are quite usual and recurrent phenomena, their causes are still unclear. Both terrestrial and extra terrestrial reasons have been suggested. Sometimes it is argued that cutting down trees causes drought. An experiment conducted in Colorado has shown that cutting down trees does not affect rainfall. Trees were planted in two large regions and the rainfall was recorded for a number of years in these two areas. Trees were cut down in one place and again rainfall was recorded for a number of years. There was no significant changes of rainfall in the area where trees were cut down. Trees are grown upto tens of feet only whereas rain is an uper atmospheric phenomenon forming at a height of several thousand feet up and hence trees are not expected to affect the rain formation. The forests are cut down gradually, their population is decreasing monotonically, whereas in the case of drought, we find some cycles, some periodicities though irregular. Forest was not much larger in 1980 than in 1979, but we find there was more rainfall in 1980 than in 1979 specially during January to May.

Forest is a resource by itself and we must make proper and planned use of it. If we use up all the forests say during the next ten years, how shall we meet our demands on wood for fuel, furniture, house building and industry in the years thereafter ? As it takes time for the trees to grow, we must transplant more trees than we cut down. Moreover, forests make microclimate more cool and damp around them. Deforestation makes the soil lose retaining capacity of water, causes erosion of soil etc and as a result, rain water runs quickly, cuases flood and sedmimentaiton and the productivity of the soil also decreases. Large scale destruction of forest may contribute towares climatic change of the earth and hence towards occurrence of drought. Hence even if the forests do not contribute to increased rainfall, we must encourage forest cultivation to the desired level of 25% of the whole country area.

The occurrence of drought seems to be due to complex factors. Though climatic change of the earth is taking place continually, occurrence of a drought does not necessary mean a climatic change though certain types of climatic change can mean more drought. Usually more droughts occur during colder climate. The earth in its 5000 million year history has undergone several cycles and of several orders of warm and cold periods. During its history, the earth was completely ice free unlikle its present condition for most of the time. It takes several hundred million years to pass from ice age condition to ice free condition and this is related to the time the whole solar system, the sun together with all its planets including the earth takes to make a

complete revolution in the galaxy. Presently we are passing through an ice age which is 2-3 million years old. Again during an ice age, there are relatively colder and warmer periods known as glacials and interglacials. Presently we are passing through a warmer phase-an interglacial which is about 10,000 years old.

It takes about 100,000 years for glacial-interglcial cycle to occur and this is related to the change in the orbital parameters of the earth. About 30% of the earth's surface was covered with ice during the maximum phase of the last glacial about 18,000 years ago compared to about 10% today. There are smaller cycles of warm-cold periods like the 2600 year periodicity of little ice ages. The northern hemisphere suffered from the last little ice age starting from around 1400 AD to 1980 AD. Widespread drought occurred during this period. From 1900 AD, the northern hemispheric temperature started rising up until 1940 AD. From 1940 AD, the northern hemispheric temperature started declining upto 1978 and started rising again. It has been found that if there is more snow and cold in Eurasia, then there is less rain in our region.

If we study changes in the upper air chart during a cold period we find a change in the thickness of the 500 mb. pressure surface. The upper air flow in the northern hemisphere is dominated by westerly winds which whirl round the hemisphere and is known as the circumpolar vortex. This vortex expands southwards when cooling takes place and the whole climatic zone shifts southwards.

In Bangladesh the pre-monsoon rain is due to the travel of western distrubances combined with the influx of moisture from the Bay of Bengal and Arabian sea. If there is more cold, this may mean lesser number of western disturbances and also less moisture and consquently there may be less rain and so drought will occur. The sun is the life giver of the earth's climate. If is ceases to shine the earth will freeze in a matter of days, all life on this planet will cease and there will be none to study the climate. The mechanism by which the sun can cause the climatic changes on the earth is not known precisely. A decrease of solar radiation by 1% can cause a temperature decrease of the earth's surface by 1.5^{O}Cc and hence less rain and some more drought. But the degree by which the solar electromagnctic radiation changes with time is not known with certainty. It is not very accurately known whether the solar constant which is defined as the intensity of the solar radiation received at the earth's distance per unit time per unit area and measured outside the atmosphere changes or not.

Certain phenomena on the surface of the earth like geomagnetic storm, upper atmosphere density show positive correlation with solar activity. This is usually measured by observing the number of sunspots and the number of groups in which they occur. The solar activity, on the average has an

eleven year cycle but drought does not have an eleven year cycle. In the USA, drought showed a 22 year periodicity which coincided with the double sunspot cycle for a number of years but after sometime it did not persist. In Bangladesh we have a 5-10 year periodicity in drought which may be more related to the electromagnetic radiation emitted by the sun, which we have yet to study. The atmoshere and the oceans which control the earth's climate have certain rhythms and the fluctuations in rainfall may be the result of these rhythms.

5.5 MAN MADE ACTIVITIES

Man through his activities has started acting as an agent of climatic change. He is releasing enormous quantities of CO_2 (carbon dioxide) by burning both fossil fuels and non-fossil fuels (including burning wood). Part of the CO_2 is absorbed in the ocean and part is released in the air. It is estiamted that since 1860, the CO_2 content in the atmosphere has risen by about 10-15% and will continue to rise further in future and may double by the middle of the centruy. CO_2 can increase the temperature of the lower atmosphere by re-emitting back part of the radiation emitted by the earth. Thus this can definitely change the earth's climate. Large scale increase of the earth's temperature has been predicted because of the increased amount of CO_2 in the atmosphere in future. Manmade aerosols (particles released from industrial activtiy etc) can also affect the earth's climate. Computer studies have indicated that if the particles are very close to the earth they warm the earth's surface whereas if they are at sufficient height, they produce cooling effect by screening out part of the solar radiation.

5.6 DROUGHT INDICES

Is there an objective way of describing drought ? Various indices have been devised for this and some of them are described below :

Precipitation Effectiveness Index

$$P.E.I = 115 \left(\frac{P}{T-10}\right)^{10/9}$$

Where P is monthly values of Precipitation in inches and T is the temperature in degrees Fahrenheit. Summation is carried for twelve months.

The following categories of climate types have been defined on the basis of P.E.I. values.

Climate Type	Vegetation	P.E.I. Values

Wet	Rainforest	>	127
Humid	Forest		64-127
Sub-humid	Grassland		32-63
Semi-arid	steppe		16-31
Arid	Desert	<	16

This index denotes better an index of climatic types. Values of a few stations in nortwestern Bangladesh have been computed and his shows that values for this index ar nearer to 100 during dry years indicating that the climate type considering the whole year is humic. The vlaue of the Index is more for other regions of the country.

5.7 EFFECTS

We have seen that even though there is abudant rainfall in Bangladesh, drought may effect us seriously at least for some months. The consequence can be serious. In general there ia a direct relationship between rainfall and crop yield. During flood years, though there is damage of crops temporarily, there is increased production in the following year. Crop damage to the extent to some 10% is possible in the case of severe drought.

5.8 REMEDY

There is no easy remedy for phenomenon like droughts. Experiments on artificial rainmaking is being carried out in various parts of the globe. In Bangladesh, such experiments may be carried out on an experimental basis. If successful, the problem of drought may be tackled to some extent.

In addition, innovative methods have to be developed to combat drought like irrigation by using underground water, storage of water by damming etc. It is very difficult to make long term prediction of drought but research work should be undertaken for its prediction so that its affects can be mitigated properly.

Methods should be developed to predict droughts so that farmers could irrigate their land in time.

6.1 RISK INSURANCE

There should be a detailed and thorough study of risk factors due to various natural disasters described in this paper

such as tropical cyclones, floods, droughts etc. for each region in Bangladesh. This should enable insurance companies to introduce agricultural risk insurance. This could form a part of a modern system of risk management in agriculture.

==========