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# Space Technology in Disaster Management

Aishwarya Narain

**Abstract-**A disaster management support program (DMSP) at ISRO has been undertaken at Space Applications Centre, ISRO under the 10th plan (2002-2007). The program addressed the various stages of disaster like pre-disaster planning, during and post disaster. The program is being continued into the subsequent plan periods including the present 12th Plan of the Government of India. An integrated approach of using Remote sensing and Communication system like disaster warning Radar system and many other portable communications systems with satellite link developed at the Space Applications Centre of ISRO were found very suitable. The remote sensing applications were started with the use of Landsat data and aerial photos and later made use of the all weather Synthetic Aperture Radar. For example in flood damage assessment it was assessment in terms of the extent of flooding and progressive inundation using multi date data from Radarsat-1 Canadian Space Agency (CSA). Today with the launch of RISAT in 2012 by ISRO, an all weather indigenous capability to monitor and assess disasters in near-real time has been achieved. Bhuvan, a web based geoportal launched by ISRO to showcase the capabilities of Earth Observation from Indian Remote Sensing Satellites has enhanced the outreach of remote sensing observation for natural resources besides disasters amongst the users and decision makers.

**Index Terms-**Space Technology, Disaster management, Radar systems, Portable Communication Systems, multi date data

## 1 INTRODUCTION

THE geographical location of the country is such that it is subjected to disasters with varying intensity and timescales in different part of the season. Some of the frequent ones occurring almost every year in some or the other region of the country are floods or drought, the landslides in the hilly regions besides less recurring like earthquake. The other type occurring in some specific periods is the cyclone causing flooding in the coastal region on varying scales. On relatively small scales are avalanche and forest fire frequently reported in the Himalayan region in northern India. It is reported that amongst the 36 states/union territories as much as 22 are disaster prone. Although the community has adapted to such disaster of regular occurrences, it is observed that almost every year the economic and social losses are on an increase year after year. River floods are the most frequent and devastating. The major input is the summer monsoon rainfall during the short period of 3-4 months, which is almost 75 per cent of the total annual rainfall. The result is the heavy discharge from the river causing wide spread flood. It is estimated that ~ 40 million ha. area has been identified as the flood prone. On an average 18.6 million ha. of land is flooded annually. Most of the floods (> 60 per cent) are expected taking place in the Ganga-Bhramputra-Meghna basins. As against floods, the other major disaster frequently occurring is drought in some states. It is estimated that about 16 per cent of country's geographical area is drought prone and affects more than 50 million people on an annual basis.

As much as 8 per cent of the total sown area of the country is drought prone covering the arid, semi and sub-humid regions. The long coastline (mainland: ~ 5700 km.) of the country is subjected to cyclone originating in the Bay of Bengal and the Arabian Sea. The Indian Ocean is one of the six major cyclone prone regions of the mid-ocean. Cyclone activity is confined mainly during April-May and October-December. As much as 80 per cent of the total cyclones formed are on the east coast. Many of these have been reported to have a devastating affect in the past. The most infrequent and impossible to predict amongst the various disasters are the earthquakes. However there is a good understanding as regards the seismically active areas of the country, which is 50-60 per cent of the total area and much of it is confined to the Himalayan, Sub-Himalayan and in Andaman and Nicobar Islands. In recent years, SAC has developed a large number of communication systems which make use of the transponder on the Indian National Satellite (INSAT) and its utility has been demonstrated for establishing audio/ video communication in the disaster affected areas.

The meteorological payload-Very High Resolution Radiometer (VHRR) on INSAT has been successfully used in tracking the movement of cyclones and forecasting the likely areas to be affected. This has led to mitigation of disasters by moving the people and livestock to saferplaces. Similarly, use of high-resolution remote sensing data from the constellation of Indian Remote Sensing Satellite (IRS) has been found useful in damage assessment.

## 2 DISASTER AND MANAGEMENT ISSUES

There are different types of disasters encountered in different parts of the country varying in magnitude and occurrence. The following are the types of disasters based on its frequency:

- *Aishwarya Narain Nascent Info Technologies Pvt. Ltd, Ahmedabad*
- *Formerly Project Director, DMS program, SAC (ISRO), Ahmedabad 380 015*
- *Corresponding Author : aishwarya1946@gmail.com*

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**Frequent:**

1. Drought
2. Flood/cyclone
3. Forest fire
4. Landslides

**Less frequent:**

- Oil spill and volcanic eruption

**Infrequen**t:

- Earthquake

**Others**: Industrial, Disaster and Epidemics

This is only an indicative list of disasters and not necessarily an exhaustive list. The infrequent is strictly applicable in the Indian context as is well known that almost on daily basis there are reports of earthquakes taking place in some or the part of the globe, which are regularly monitored with a network of seismic instruments.

The following are the three broad categories which typically are to be addressed for designing any disaster management system (DMS):

1. Pre-disaster planning (= warning)
2. Response (= Assessment of damage caused)
3. Post-disaster (= Recovery)

The above mentioned categories essentially represent different phases and it is observed that the most important activity spread over all these is the "mitigation" which refers to all actions taken prior to the occurrence of the disaster and that includes preparedness and long-term risk reduction measures so as to ultimately reduce the impact of disasters. Mitigation includes both planning and implementation of measures directed at reducing the possible risk associated with the disasters. In economic terms, it is fairly well demonstrated by different countries that the mitigation offers the best and cost-effective long-term method of dealing with disasters. This is achieved through optimal planning measures, which can be judiciously integrated to start with into the normal development schemes. The present status worldwide is that most of the disaster prone countries are spending huge amount of money on post-disaster relief, rescue and rehabilitation. It looks quite logical that it is better to invest on mitigation measures and finally reduce the impact of disaster losses. In the country one of the mitigation, effort very well cited is that of the experience gained from the AP Cyclone of 1977. The mitigation efforts followed in subsequent cyclonic events which made use of technological inputs like tracking of cyclone using INSAT System led to significant reduction in losses through timely evacuation, rescue and relief.

1. **Preparedness** (= Pre-disaster)

This includes the design, development and installation of early-warning systems, drafting of response procedure, conducting regular exercises and operational emergency steps including training of personnel.

2. **Response** (= during or just after disaster)

The response deals with strategies associated with search and rescue operations including evacuations, emergency medical care, food and alternate shelters.

3. **Recovery** (= post-disaster)

This activity is directed at taking all actions after the disaster once the urgent needs are accomplished. In simple terms this refers to all post-disaster activity directed at restoration of infrastructure like repair of roads, bridges, embankments, other community services like power, water supply and shelter.

It is generally observed that mitigation measures are required to be taken during all the phases of a disaster. In recent years, the technological inputs have been successfully implemented for combating some disasters like floods, cyclone and to some extent landslides including the forecasts. This has helped considerably in planning measures for early warning and the preparedness. An assessment of infrastructure requirement in vulnerable areas needs to be assessed in advance and action taken thereafter. Some of the measure's related to environmental planning can also help in reducing the impact of disasters. One of these can be suitable land use planning. Mitigation thus needs a critical study of disaster, their affect as an input to planning protection both structural and non-structural. The activities related to structural mitigation are for example flood measures, constructing disaster resistance structures and designing of retrofitting structures vis-à-vis the magnitude of disaster. Non-structural mitigation includes optimal land use planning, zoning ordinance/legislation which will prevent construction in disaster prone areas. This also includes training and education of agencies dealing with the disaster through community participation. There is a need for safer citing of emergency food storage houses, water storage tanks and other civic amenities. Areas vulnerable to disaster like flood, earthquake forest fires are well known. There is a need therefore to create a database of all known areas prone to disaster and design area specific prescription plan. The UN General Assembly Resolution 236 of 1989 launched the International Decade for Natural Disaster Prevention IDNDR (1999-2000)[1]. This was aimed at drawing concerted International effort particularly in developing countries to reducing the loss of property damage besides social and economic disruption caused by natural disaster. The core issue was to deregulate the DMS approach from rescue and relief to preparedness and mitigation. At international level the Committee on Earth Observation Satellites Disaster Management Support Group (DMSG) supports natural and technological disaster management on a worldwide basis by fostering improved utilization of existing and planned Earth Observation (EO) satellite data.

## 3 DISASTER MANAGEMENT USING COMMUNICATION AND REMOTE SENSING

In the area of disaster management, there are two major components viz., communication and remote sensing which can be very well addressed by using satellite system from

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different orbital platforms. The INSAT in geostationary orbit can provide a variety of solutions right from setting up communication links using the portable systems, which makes use of the transponder on-board the satellite to tracking the cyclones. Like-wise the remote sensing payload provides detailed spatial data (Imagery) for mapping the areas affected due to disaster leading to appropriate planning for relief rescue and rehabilitation. For example the meteorological payload-VHRR on INSAT system has amply demonstrated its use in tracking and movement of cyclones whereas the high resolution spatial data on IRS series satellites has been extensively used in assessing the extent of damage and can be used for creating a database on areas vulnerable to different types of disaster.

The activities on the disaster management support within ISRO started in a most concerted manner in the 10th plan period with an active collaboration with the Ministry of Home affairs (MHA). 3.

### 3.1. Communication

A variety of communications hardware[2] has been developed in-house which make use of the onboard system on INSAT. Such systems can be easily transported to the affected areas for audio/video transmission including transmission of imageries. In addition, these systems can also be used for imparting developmental education to the agencies involved in handling disaster related activities.

These portable systems allow the following:

1. Establishing audio/ video communication
2. Transmitting pictures of the affected area(s) for use in planning the relief and rescue measures.
3. Imparting education and training to the personnel supervising the relief operations

The following are the satellite base communication system which have been developed at SAC and their capabilities have been fairly well demonstrated in the field

#### 3.1.1 MSS Type – C Reporting Terminal

The MSS (Mobile Satellite Service) Type– C Terminal has capacity to transmit short messages (up to 40 characters).

The hardware including the spacecraft system has the following components:

- MSS Transponder with coverage area of Indian Sub Continent and surrounding seas on INSAT
- S band portable/fixed reporting terminal
- C-Band hub station (presently located and configured at the Delhi Earth Station of SAC)
- Public Switched Telephone Network (PSTN)
- User Terminal (PC/FAX)

The hub station receives the message from the reporting terminal via INSAT-MSS (S/C) transponder. A PC with Modem/Fax receives the error free messages from the hub station for use in taking appropriate action in the affected areas. The hub is designed to handle up to 16 PSTN lines whereas user terminal in turn can send the messages/instructions to a maximum of three pre-defined destinations (= administrative unit). The INSAT reporting terminals are of the three types.

1. **Portable terminal**: this can be used to provide first hand report of the affected area either by sending short messages entered through keypad or using the pre-defined standard short messages. This system is powered by Nicd batteries and has a provision to use external 12 V DC from a vehicle.
2. **Portable GPS integrated terminal:** This allows the transmission of messages along with position location. It is expected that such a system will find use in search and rescue in remote areas like tracking expedition/mountaineering, keeping track of fleet movement on the land, cargo movement in high seas besides use in affected area as part of disaster management support.
3. **Fixed type data reporting terminal:** This type of configuration is well suited for example in integrating the weather data report in coastal areas, data from stream gauges etc. This is from the point of view of acknowledging the reporting of warning as part of data reception from INSAT system.

Amongst the three types, the first one was developed as the prototype for demonstration but in due course of time GPS integrated and the fixed/ mobile type is being pursued and is being demonstrated for various user driven applications.

#### 3.1.2 Digital Sound and Data Broadcast (DSDB)

The DSDB developed at SAC is a broadcast system for transmission of multiple digital channels from a central station with a provision for sending video and audio. Also has a provision for sending the images to distant places or user defined locations. A small portable receiver with a ~60 cm antenna and simple mounting arrangement is all that is required at the receiving end. The digital data can also be routed to a PC for receiving image data and further use in the affected area/ s. DSDB when integrated with the reporting terminal can be conFig.d for acknowledging the warning messages which can be put up at a central location of IMD. Such a set up can send for example the cyclone warning/ alert signal in broadcast mode. Cyclone warning can be provided in the form of audio alarm also followed by a detailed digital message in the form of image for taking remedial measures in the affected areas.

#### 3.1.3 WLL - VSAT Hybrid Network

A hybrid network of WLL (wireless local loop) and VSAT (Very Small Aperture Terminal) can provide all types of communication solutions like audio, data and fax in a radius of 8-10 km of the affected area. A portable vehicle mounted base station of WLL can help communication between the handsets and to the base station. The VSAT can forward / receive messages to user's terminal through the satellite linked to a hub station.

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**3.1.4 Digital Cyclone Warning and Dissemination System (DCWDS)**

The DCWDS has been developed for IMD for its use in issuing warning of an impending disaster likely to hit the coastal areas. The satellite hub shall be located at IMD HQ in Delhi and the direct reception terminals at vulnerable areas on the coast. In an operational scenario the meteorological payload on INSAT will be used for tracking the movement of cyclone and that integrated with the communication system on spacecraft and the field will be used for issuing warning and also in planning for relief and rescue. Usage of such a system has been very well demonstrated on a number of occasions. INSAT services for emergency communication, dissemination of cyclone warning messages and automated data collection from remote locations have been well established. Satellite aided search and rescue services have been demonstrated particularly through participation in international programmes (COSPAS–SARSAT) also involving a large number of users like shipping industry, airport authority of India, mountaineering expedition etc. Some of the recent examples of RS data are disaster response for the super cyclone of Orissa in 1999, devastating earthquake of Gujarat in 2001 besides regular monitoring and assessment of inundation due to Brahmputra river flood to the concerned authorities.

In addition to the large number of communication systems developed at SAC, there are many, which are commercially available today. One such example is the use of satellite phones type M and mini M from INMARSAT.

**3.1.5 Training and Developmental Communication Channel (TDCC)**

The Development and Education Communication Unit (DECU) of ISRO has in recent past made use of the TDCC[3] on board INSAT for the purpose of distance education and training. One such area is support to disaster management. An appropriate continuation of TDCC had served the purpose of imparting the much-needed education and training to various relief agencies and NGOs involve in Disaster Management. In the recent past, a pilot project named Jhabua Development and Communication Project (JDCP) was implemented by DECU in the Jhabua district of Madhya Pradesh. The following were the elements of distance education implemented in this project.

- AES-SAC for uplink
- DECU-Studio for teaching and interactive TV
- 150 Direct Reception System (DRS) at selected locations
- 12 talk back DRS (TV Receive and Audio Transmit) in different blocks.
- Extended C-Band transponder on INSAT-2 Satellite

The JDCP addressed the following area of distance education and disaster management in due course of time can form one of the components

- Watershed development
- Health
- Education
- Skill Development
- Panchayati Raj

In recent years with the increased capacity of TDCC Channels such concept of distance education has been extended to other states viz., Mysore in Karnataka, Bhopal (Mahdya Pradesh), Gandhinagar (Gujarat), Bhubaneswar (Odisha). The State Remote Sensing Centre have been identified as the nodal center i.e., the ORSAC at Bhubaneswar and RESECO (BISAG) at Gandhinagar, Gujarat. Communication awareness and education are considered essential elements of disaster management in all the stages viz.

i) Pre-disaster
ii) During disaster and
iii) Post- Disaster

The post-disaster activities are aimed at educating the target audience through TDCC on aspects like what preventive measure can be undertaken impending a type of disaster. If prevention is not possible than at least precautionary, measures can be initiated. There is a need to provide immediate counseling and psychological support. The aspect of mitigation that is averting the impact of disaster to the extent possible is an important element. The audience should be educated about their right and duties as well as about different schemes and procedures to face the situation. The target group includes the victims of disaster, friends and relatives, Government organization/officials, NGOs and various funding agencies. Some of the needs towards these were immediately felt in Gujarat Earthquake of 2001.

## 4 REMOTE SENSING

Data from IRS series of satellite has been used in a variety of applications related to disaster management.

The National Remote Sensing Agency has been regularly using the high-resolution data form IRS sensors in mapping and monitoring of floods in different parts of the country. In the case of super cyclone of Orissa, the INSAT was used to monitor the track of cyclone. Due to cloud cover conditions data from RADARSAT was used for damage assessment. In the case of super cyclone of Odisha studies, IRS data could still be used to monitor the area inundated and assess the damage to Kharif Crop almost in real time. Multidate data of WiFS on IRS was used to study the changes caused similarly in the devastating earthquake of 2001 in Bhuj and its environment. Pre- and post-earthquake images clearly brought out that there was an activation of a number of channels in the great Rann of Kachchh around Kharda, Khadir, and Bela, which subsequently dried up and almost returned to the pre- earthquake situation. The extent of damage to the urban settlement in Bhachau was similarly estimated using high-resolution aerial data. Techniques have been developed at SAC to study frequently occurring landslides in the Himalayan region and
Remote Sensing data was found useful in:

- Inventory

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- Assessment
- Warning and
- Risk Zoning

In this study, thematic layers of various Geo-environmental units like geomorphology, geology, lithology, vegetation, and drainage from a variety of sources including remote sensing data were integrated in the GIS environment to map zones and their susceptibility to slides. Similarly, techniques have been developed at SAC to map areas affected due to forest fire. A case study was completed in the GIR, Protected Area, of Saurashtra, Gujarat to develop methodology for "Fire Risk" zoning wherein remote sensing data besides a host of other parameters were integrated using GIS.

**4.1 Case Studies**

The following are the three **case studies**, which have been discussed in respect of technique development/operational demonstration in the area of:

- Cyclone caused damage assessment
- Landslides in the Tehri Reservoir Rim Area
- Flood damage Assessment using Radarsat.

**4.1.1 Cyclone caused Damage Assessment of Krishna Delta (CASE STUDY I)**

The study dates back as one of the earliest effort made of using the remote sensing data for damage assessment[4]. A 2-Step procedure was used viz. LANDSAT Image (Pre and Post event (**Fig. 1**) and large scale aerial photographs to assess the damage caused due to the devastating cyclone which hit the AP Coastal area on 19th November 1977. The storm sea-surge developed to about six meter affected an area of 80 km in length and 16 km in width of the Krishna delta region. The following is the detail of the 2-step approach used in this study.

1 Analysis of pre-cyclone image (Step – I)

Visual interpretation of the pre cyclone imagery (23 October 1972) of Landsat showed three distinct coastal zones viz., delta front sand, low land/wetlands and uplands/agricultural area. Two fold purposes were served in the analysis i.e. delineate the upland in relation to the wetlands and secondly to determine the general morphology of the affected area to understand the inundation phenomenon. The extent of inundation and prominent changes in the coastline including spits were deciphered from the post-cyclone imagery available (28 November 1977), which was asynchronous with the inundation. Nevertheless, the extent of flooding could be affectively mapped. It was observed that the extent of flooding lie almost within the high flood limit.

2 Study of Air photos (Step II)

A detailed analysis of the semi-controlled mosaic of air photographs could identify the upland/agricultural area and wetland. Acreage estimates were given for the various categories in the agricultural area and built-up land including the line km of embankment damaged. It was observed that most of the hardest hit areas are adjacent to the coast with a small proportion of mangrove. A cost benefit analysis was also carried out to highlight the efficacy of remote sensing technique.

**4.1.2 Landslides Identification/zoning in the Tehri Reservoir Rim (Case Study – II)**

Techniques were developed using IRS LISS II and SPOT MLA and 71 slides were mapped in Bhilangana and Bhagirathi reservoir rim area (36 during field visit and another 25 on image alone)[5]. Only four were found to be misinterpreted. Geo-environmental theme unit maps were prepared using IRS data like geomorphology, lineament, land use, slope and lithology (from published data). These were integrated in ARC/INFO GIS with appropriate weightage assignment and finally a hazard zonation map was generated (**Fig. 2**).

**4.1.3 Use of RADARSAT DATA in EAST UP Floods of 1998**

RADARSAT data was used in absence of cloud free images from IRS to assess the extent of flood damage in the Eastern UP during 1998[6]. The floods were caused by the Rapti and Ghaghra rivers resulting from heavy rainfall breaking records of the past several years. More than 20 embankments were reported to be breached along the Rapti and a few along the Ghaghra river.

Three data sets in different modes were acquired to study the floods, September 1 (Scansar narrow; **Fig. 3**) August 30 (SAR Standard) and August 3 (SAR extended) 1998. Data of August 30 and 3 having identical overages were found useful to study the progressive inundation. Data of September 1 (333 km$^2$) was found extremely useful to study the total extent of floods in districts of various revenue divisions. Flood affected area was estimated along with the mapping and inventory of villages on 1:50,000 scale. An area of 5.37 lakh ha was affected with about 4276 villages/ settlement inundated. In the context of cultural land, it can be stated that the total loss to the cropland can be taken as 70 per cent of the flood area i.e. 3.76 lakh ha. Unit Cost of this kind of damage assessment from satellite data was found to vary from Rs. 2 to Rs. 20 per sq. km. corresponding to the resolution of the data used i.e. 25 m and 8.5 m respectively.

The information thus generated was found useful for planning relief measure in view of the fact that even as late as second week of September many areas were reported inaccessible. The total analysis was completed with a fortnight from the reported occurrence of the flood. Simple visual interpretation techniques were used and it demonstrated the capabilities of Radarsat to acquire data within 48 yours of the request and its availability on internet in the next six hours. It was concluded that a database created in GIS could be useful for planning remedial measures in the future.

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#### 4.1.4 Disaster Management

An elaborate program of disaster management with linkages with concerned Government Departments in particular Ministry of Home Affairs (MHA) was initiated in the 10th Five year plan (2002-2007) and is being continued into the 11th plan and is currently being pursued in the current 12th Plan (2012-2017). An elaborate program with inter-center involvement of ISRO led to the following:

- An airborne C-band DMSAR (Disaster Management Synthetic Aperture Radar) was developed and extensively flown to collect flood signature data and also at times for use in correction and calibration of space-borne SAR system.
- Launch of RISAT (Radar Imaging Satellite) in 2012 provided the indigenous capability to have its own radar satellite system in orbit.
- Generation of close contour data of areas vulnerable to floods/ cyclones and landslides using the Airborne Laser Terrain Mapping (ALTM)
- Modelling techniques in flood forecasting besides techniques for damage assessment.
- Demonstrating the applicability of a GIS based decision support system for a disaster
- Landslide zonation at 1: 10000 or larger and a GIS based impact assessment scheme
- End-to-end pilot study for demonstrating the forest fire monitoring and damage assessment. Defining sensors for surveillance from geostationary orbit
- Cyclone tracking and movement including space inputs to weather model
- SAR interferometry and GPS for precise movement in seismically active areas
- Setting up of Decision Support Centre (DSC) at National Remote Sensing Centre (NRSC) under the DMS Program as a single window service provider for disaster service. It operates on 16X7 basis during normal time and 24X7 in the event of disaster.

#### 4.1.5 Geoportal – Bhuvan

Under the National Natural Resources Management System of the Planning Commission, DOS is the nodal agency for its implementation. The main aim is the optimal utilization of natural resources by integrating conventional data with that derived from remote sensing satellites besides providing these information to users through web based services.

This has led to the launch of Bhuvan, which is the geoportal and is maintained by the National Remote Sensing Centre (NRSC). NRSC is conducting the remote sensing applications as well as services drawing support from its own Regional Remote Sensing Service Centres located at Dehradun, Jodhpur, Kolkata, Nagpur and Bangalore and involving State Remote Sensing Centres in Nation-wide remote sensing projects leading to thematic map generation. All this is organized and available through Bhuvan to users for geospatial services. The portal is providing near real time information on various types of natural disasters. As of now it is also allowing the free download of 23 m LISS-III data for analysis and understanding the potential of remote sensing data for use by scientists and engineers concerned in the study of natural resources.

## 5 CONCLUSIONS

An integrated approach using satellite communication including developmental education through TDCC channels and remote sensing has provided a viable input at various stages of a disaster. This ultimately has led to defining the various components of a disaster management system. A large number of activities to start with were proposed in ISRO's tenth plan to support the disaster management and significant progress was made in the subsequent plan periods. This activity continues in the ongoing 12th Plan.

Today many of the disasters like flood, fire, landslides, and drought are being routinely monitored in active collaboration with the concerned Dept. of GOI and State Governments. The information thus extracted is shared over Bhuvan, the geoportal managed and hosted by National Remote Sensing Centre, Hyderabad. Launch of Radar Imaging Satellite (RISAT) has significantly enhanced the capability in monitoring and assessment of some disaster in near real time during cloud covered conditions.



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Fig. 1. Pre and Post cyclone images from Landsat.

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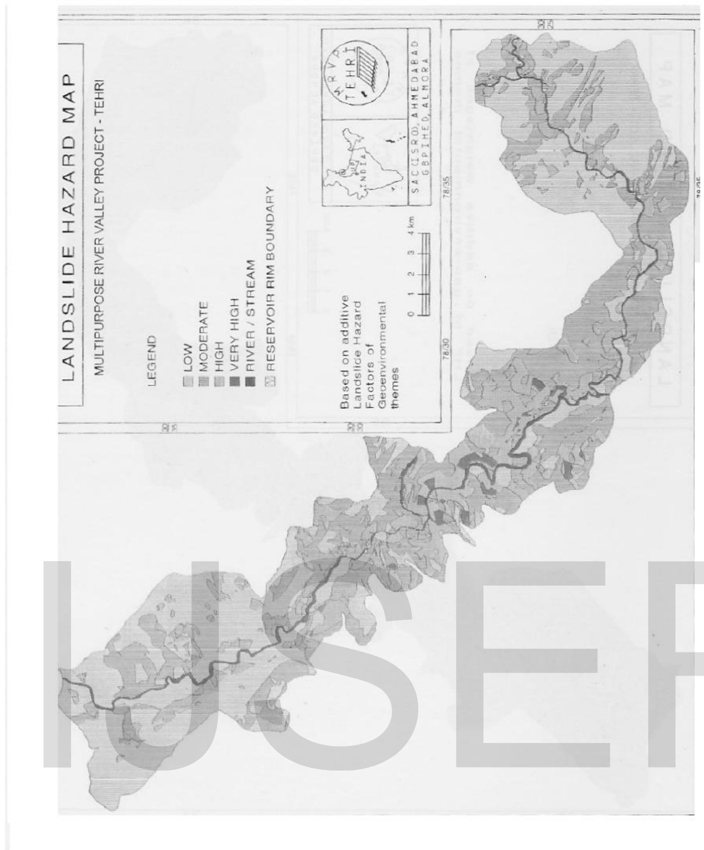




Fig. 2 Landslide Hazard Zone Map

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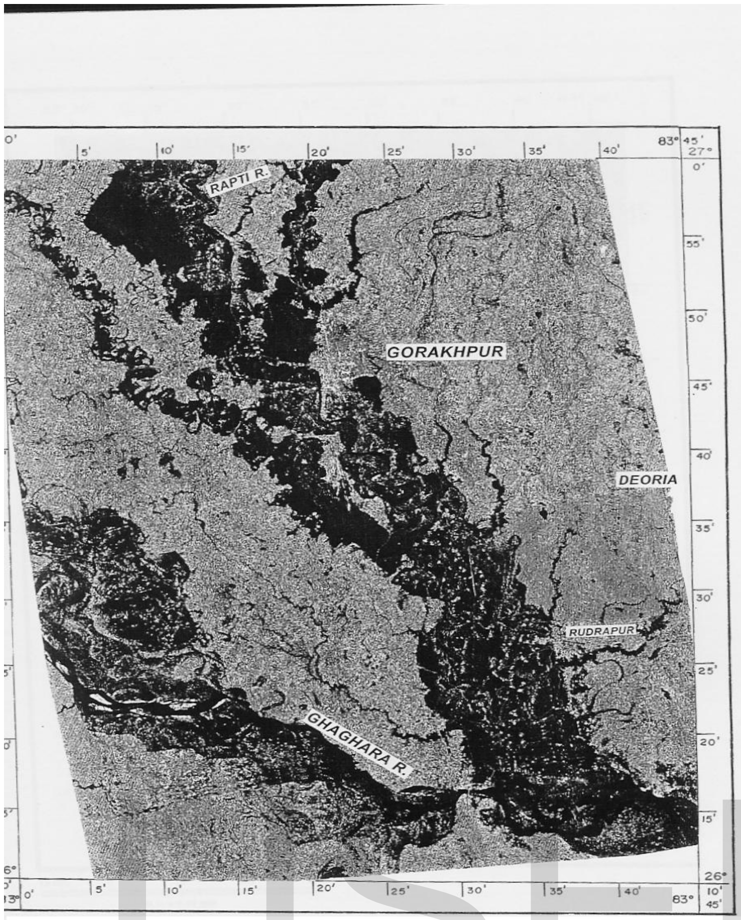
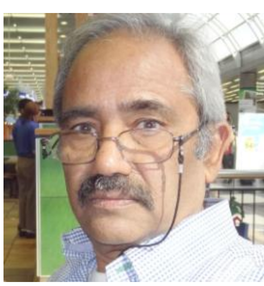



Fig. 3 Radarsat image (September 1, 1998) covering parts of East UP districts showing inundated areas

Aishwarya Narain