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Flood Inundation Mapping Through Satellite Remote Sensing - Indian Experience

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Abstract : *In our country an area of about 42 M.ha. is susceptible to floods every year resulting in a corresponding average annual losses of Rs. 2500 crores in monetary terms. Conventional methods of assessing flooded area and consequent damages are subjective and too time consuming. Remote Sensing on the other hand is objective and on near real time. Although remote sensing is not a substitute for conventional methods, yet it saves a lot of effort and time. Remotely sensed data either in the digital format or in the imagery form can be quickly analysed on a computer or visually, as the case may be, to provide reliable estimates of flooded area and resulting damages. Over the past one decade sufficient expertise has been built up in the country and the methodology operationalised in flood mapping. With more satellites in orbit, availability of microwave data anticipated in near future to get over the problem of cloud cover, it is expected that flood damage assessment will be refined and routinised.*

1. Introduction

Occurrence of floods is a natural phenomenon and in the Indian context with variation in topography, climate, rainfall etc. the country has been experiencing flood and drought cycle in different parts of the country. The problem of flood in the country varies from year to year and region to region. It has been estimated that an area of about 42 M.ha. is susceptible to floods in India.

The floods occur mainly during the monsoon with attendant bank erosion and drainage congestion. Extensive devastation due to floods is more frequently experienced in the States of Assam, West Bengal, Bihar, Uttar Pradesh in the Brahmaputra and Ganga basins and parts of Orissa. It is seen that on an average about 8.6 M ha. of land area in the country is annually affected due to floods resulting in average annual damages of the order of Rs. 2,500 crores including damages to crops, houses and public utilities. The area affected and the damage assessed during the last 8 years are given in Table-I.

Table 1 : Land area affected due to floods and annual damage

Year	Area affected (in M.ha.)	Damage assessed in crores of Rs.
1981	6.02	1196.5
1982	8.87	1644.3
1983	9.02	2491.6
1984	10.76	1905.6
1985	8.38	4059.3
1986	8.81	3748.5
1987	11.35	2569.7
1988	23.95	5009.54 (tentative)

According to the existing procedure Revenue Deptts. of the State Govts. are made responsible for coordination and publication of flood damage statistics. These data give an idea of the havoc caused by floods and enable to assess the flood problem affecting various parts at any time. Another use of such statistic has been for determining the extent of relief including suspension/remission of land revenue etc.

The present method of flood damage assessment has a built-in-bias towards over-estimation on account of several reasons. Further, the system of assessment and reporting of flood damages is too time consuming and it is subject to human errors and manipulation. The returns are generally not sent in time. For reliable flood damage assessment and to effectively attempt the flood loss reduction all valuable areas need to be demarcated and coordinated, structural and non-structural measures taken up for flood measurement.

It is essential that systematic and timely assessment of flood affected area are to be done based on data with the required accuracy for rational assessment of damages. The modern technology of remote sensing though not a substitute to conventional methods of survey can fulfil many of the requirements. The high degree of adoptability provided by satellite data in the near infrared region for water-body identification and mapping has rendered this hitherto tedious job easy, near real time and accurate for the resource scientist/manager.

2. Type of Data and Analysis

Flood inundation mapping helps in flood mitigation measures and landuse planning. Remote sensing is cost effective when large areas are to be covered for selecting problem spots for intensive study. The synoptic coverage of the extent of flooding can now be obtained very quickly because several satellites with varying revisit capabilities are in orbit more so with the launching of IRS-1A satellite which has the capacity of covering adjacent paths in consecutive days. The satellite remote sensing technology is extremely useful in monitoring the dynamics of water spreads during the floods. Increased soil moisture, moisture stressed vegetation and standing water which result in reduced reflectivity that lasts up to two weeks after the events are all indicators that help delineation of flood inundated areas on a post-flood imagery.

Scale of investigation required to determine the type of remote sensing platform. The resource satellites provide imagery with resolutions varying from 10 m (SPOT, panchromatic) to 80m (landsat 5, multispectral). However, for detailed delineations, infra red aerial photography is extensive besides having procedural complications and as such finds extremely selective application. Under these circumstances SPOT data with 20m resolution in multispectral mode besides the 10m resolution in panchromatic mode provides an alternative.

Analysis of satellite data can either be by visual interpretation or by digital methods using a computer. The visual interpretation gives a reasonably accurate assessment of water spread directly from the satellite images.

It is often possible to delineate different stages of soil moisture as shallow inundated or deep inundatad depending on tonal/colour differences. In the digital analysis, the computer classifies each pixel into water or non-water categories by comparing their individual reflectance values with the low reflectance of water bodies in the infra-red region.

3. Data inputs and Methodology for Visual Interpretation

Hard copy data products of different satellites either B & W or FCC are the required inputs. B & W image in infra-red band allows delineation of water bodies and flood inundated areas but FCC would provide additional information such as silt concentration in flood water and partially or wholly inundated crop lands. The technique of interpretation involves an integrated assessment of judicious combination of various recognition elements. The capability/efficiency of the interpretor plays a paramount role in the quality of final results.

4. Data inputs and Methodology for Computer Assisted Image Interpretation

The requirement of data products is in the form of computer compatible tapes/compact floppy discs. These products would be utilised on a suitable computer system by integrating the ground information as training sets for bringing sharper refinements in the data outputs for a visual impact of the actual areas which are flood inundated. It will be very easy to compute the areas of different categories of flood inundation and provide information almost in a near real time.

5. Indian Experience

Way back in 1980, when India was still a toddler in the field of remote sensing, Central Water Commission entrusted the study of record flood of August, 1977 of Sahibi river to NRSA. For this purpose, NRSA procured the landsat data from USA, analysed it both visually and digitally and came up with maps depicting pre-flood, flood and post-flood conditions as well as flood inundation maps. The studies so conducted were verifed with the the Aerial Svrvey carried out during the occasion of flood and the results obtained from satellite survey closely tallied with Aerial Survey results thus establishing the use of remote sensing techniques for such mappings. Since then, encouraged by the success of the project, NRSA proceeded with flood inundation mapping of important flood events in the country on their own/at the instance of State Govts. etc. Thirteen flood events of 1988 mapped by NRSA are listed in table II.

The studies carried above were on near real time basis and the flood maps have been distributed to all the concerned authorities affected by the flood and also the Central Government authorities concerned with the flood management. The flood mapping is only a part of the process of flood management. In addition to flood mapping, it is necessary to know the flood damages also for evaluating the losses. During the year 1988 NRSA have attempted the flood damage assessment for some districts in Brahmaputra and Ganga basins. Their assessment of extent of crop area damaged and its value in rupees together with the conventional methods are listed in Table III & IV.

It can be observed that the details of extent of crop damage with its value assessed districtwise both by satellite and conventional methods are presented in tables III & IV vary widely in many cases. The variation is more apparent in Table IV. Such a wide variation may be partly attributed to the difficulty in delineating district boundaries exactly, extrapolation of flood affected crop area under cloud cover, satellite flood mapping using small scale imagery and adoption of flat rate per hectare of affected crop area in damage assessment etc. Although the statewise totals reflect some narrowing down of the

Table II : Flood events of 1988 mapped by NRSA

Sl. No.	Date of imagery	Satellite Data used	Name of river	Area covered
1.	30.5.88	IRS	Brahmaputra	Guwahati (Assam)
2.	31.5.88	IRS	Brahmaputra	Goalpara (Assam)
3.	3.6.88	Landsat TM	Brahmaputra	Nowgong (Assam)
4.	13.5.88	IRS	Brahmaputra	Dibrugarh (Assam)
5.	15.7.88	IRS	Tista, Jaldaka, Torsa & Raidak	Part of West Bengal
6.	17.7.88	Landsat TM	Kosi	Madhubani & Darbhanga Distt. (Bihar).
7.	30.7.88	Landsat TM	Brahmaputra	Dilbrugarh (Assam)
8.	5.8.88	IRS	Brahmaputra	Goalpara (Assam)
9.	21.8.88	Landsat TM	Ganga	Fatehgarh (U.P.)
10.	30.8.88	Landsat TM	Ganga, Ghagra & Yamuna	Raebareuku (U.P.)
11.	2.9.88	IRS	Ganga, Ghagra & Rapti	Varanasi (U.P.)
12.	23.9.88	Landsat TM	Brahmaputra	Nowgong (Assam)
13.	27.9.88	Landsat TM	Beas, Ravi & Sutlej	Punjab, H.P. & J & K

Table III : Extent of crop area that would have been damaged during 1988 Floods in Brahmaputra basin (excluding Barak portion in the districts of Assam assessed from satellite data and by conventional methods and its value in Rupees).

Sl. No.	Districts	Area in thousand ha.		Value in rupees crores	
		Sat. *	Conventional**	Sat.*	Conventional**
1.	Nowgong	1.39	1.526	34.75	13,86
2.	Darang & Nalbari	0.70	1.895	17.50	14.07
3.	Kamrup	0.89	1.542	22.25	0 08
4.	Barpeta	0.93	0.984	23 25	0.64
5.	Dhubri	0.73	0.795	18 25	65.19
6.	Lakhimpur	1.11	0.801	17.75	98.16
7.	Dibrugarh	0.10	0.824	2.50	7.10
8.	Jorhat	0.32	0.641	8 00	3 63
9.	Sonitpur	0.48	0.598	12.00	9.02
10.	Sibsagar	0.55	0.412	13 75	3 33
11.	Golpara	0.30	0.255	7.50	0.33
12.	Kokrajhar	0.49	0.239	12.25	—
	Total	7.99	10.512	199.75	215.11

* source : NRSA. Hyderabad

** source : State Governments

Table IV : Extent of crop area that would have been damaged during 1988 floods in Ganga and its tributaries (in the districts of Bihar assessed from satellite data and conventional methods and its value in rupees).

Sl. No.	District	Crop area affected in Th. ha. (approx.)		Value in rupees crores	
		Sat. data*	Conventional**	Sat. data*	Conventional**
1.	Aurangabad	1.30	—	0.16	—
2.	Begusarai	12.50	5.00	1.56	0.53
3.	Bhagalpur	28.10	12.00	3.50	2.52
4.	Bhojpur	6.10	1.00	1.01	0.08
5.	Champaran East	21.90	7.00	2.74	—
6.	Champaran West	16.90	12.00	2.11	1.41
7.	Darbhanga	0.20	4.40	0.76	6.27
8.	Gaya	1.90	—	0.24	—
9.	Gopalganj	2.50	31.00	0.31	6.25
10.	Katihar	30.00	65.00	3.75	15.02
11.	Khagaria	22.50	18.00	2.81	1.25
12.	Madhepura	11.30	2.00	1.41	0.02
13.	Madhubani	7.50	10.00	0.94	0.51
14.	Munger	12.50	1.00	1.56	0.10
15.	Muzaffarpur	7.50	5.00	0.94	—
16.	Patna	15.60	5.00	1.95	3.74
17.	Purnea	54.40	15.00	6.80	0.85
18.	Saharsa	9.30	47.00	1.16	1.88
19.	Samastipur	14.40	17.00	1.80	1.18
20.	Saran	16.20	—	2.03	—
21.	Sitamarhi	9.40	27.00	1.18	1.65
22.	Siwan	5.60	25.00	0.70	1.86
23.	Vaishali	4.40	—	0.55	—
24.	Chapra	—	40.00	—	3.76
25.	Sahebganj	—	6.00	—	0.99
26.	Singhbum	—	—	—	—
	Total	320.00	395.00	39.99	49.87

* Source : NRSA

** source : State Governments

variations, further refinement is called for in assessment by satellite methods. Remembering that crop damage assessment was attempted for the first time in 1988, it is hoped that further experimentation would help in achieving acceptable results.

The flood mapping has reached a stage of operationalisation and in course of time the flood damage assessment will also be operationalised.

To attend to the various resource problems the State Govts. have established their own Remote Sensing Centres for the application of this technique to the various resources monitoring. In order to help the user community, the Standing Committee on Water Resources recommended that a flood monograph map be prepared and circulated to the users. Accordingly, a flood monograph has been prepared and is under finalisation.

6. Conclusion

The work done so far in the country amply proves the suitability of application of the modern technology of Remote Sensing to flood mapping There is more need for flood damage assessment, which will be the goal in future years. With more satellites with finer resolutions in the orbit and cloud cover eliminated with microwave mounted satellites launching in the offing, more satellite data at frequent intervals will be available; which will render the process of flood mapping/flood damage assessment and its routinisation more easy.