Identification of flood affected areas – need for a scientific approach

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Abstract

Identification of flood affected areas is an important input for taking up flood management schemes for alleviating the problems of the people affected by floods. Rashtriya Barh Ayog attempted in 1980 to quantify the area liable to floods and arrived at figure of 40 m.ha for the country. Subsequently, many states reported significantly enhanced figures of Flood Prone Areas to Working Group for Flood Control Programme for Xth Plan. The Working Group expressed concern about the authenticity of figures given by some of the states and suggested a review. The RBA had also advised the State Govts. to work out the flood prone area in a scientific manner.

The paper describes an efficient and scientific approach with suitable illustrations to map near real time flood inundation. Flood inundated areas of some of the districts of Bihar have been worked out for a particular satellite scene to establish the effectiveness of using remote sensing data as a tool to map flood inundated areas. The methodology of identifying flooded area district wise, as discussed in the paper, is topical in view of the District wise Flood Prone Area Development Programme likely to be launched by the Planning Commission during XI Plan. The paper also highlights the application of satellite imageries to assess the damage caused by floods.

Introduction

Identification of flood affected areas is an important input for devising the strategy for efficient management of floods. The severity and scale of flood management works depends upon the magnitude of flood prone areas and frequency of occurrence of flooding in the area. Rashtriya Barh Ayog in 1980, various Expert Groups and Working Group for Flood Control Programme for Xth Plan have in their reports highlighted the concern about the authenticity of flood prone area figures reported by some of the states and suggested a scientific approach to identify the flood prone areas.

Analysis of satellite remote sensing data is a powerful tool for identification and quantification of water spread area. Advantages of the information acquired by satellite remote sensing are its synoptic coverage, repetivity, near real time data availability and ease of data collection before, during and after the flood event. Various satellites having sensors operating both in the optical as well as in the microwave range of the Electro Magnetic Spectrum at different spatial resolutions can be used for obtaining valuable information on flood affected/waterlogged areas. WiFS sensor, which has got wide swath of about 810 km and a repetivity of 5 days, proves to be very effective in monitoring flood affected areas at the state level, while LISS - III and PAN sensors can be used to provide the details for the affected area. With IRS-1D and P6 in orbit, the effective repetivity of WiFS sensor is thrice in five days. However, one of the major disadvantages of the optical sensors is the non-availability of cloud-free data during monsoon season because of adverse cloud conditions. Microwave data from ERS and RADARSAT have got cloud penetration

capability and can effectively be used in such cases for flood mapping. The paper presented here describes the effectiveness of the use of remote sensing technique with suitable illustrations to map near real time flood inundation of some of the districts of Bihar.

A Rethink on definition of Flood Prone Area

As per RBA, the maximum area damaged/affected in any one of the years is assumed to be the area liable to floods in the state. The total of such maxima of the various states is considered to be the area liable to floods (Flood Prone Area) in the country. The RBA, however, recognized that annual flooding is not coextensive and that different areas are often flooded in different years by different streams. As per CWC records, the maximum area affected in any year in the country is 17.50 m ha. as against area liable to floods as 40 m ha. based upon data of 1953-1978. The figure of 40 m ha. includes protected area of 10 m ha. which is not actually flood affected.

The flood prone area estimated as 40 m ha. can only be expected to increase over the years (as it is based on the maxima of areas flooded as per the past available record). By the very definition of flood prone area, the figure does not reflect the effectiveness of the flood management works undertaken. It is suggested that criterion of actually flooded area, say in the past 10 years, would be more appropriate index to gauge the severity of flood problem in the state. The effect of flood management works undertaken in the state in reducing the flood affected area could also be monitored more effectively. Review of flood affected area in a state can be undertaken at the end of every Five year Plan.

Need for Scientific Approach

Rashtriya Barh Ayog, 1980 in their report have observed that the figures of area prone to floods is more an estimate based on some judgement rather than a reliable basic data to prepare a Perspective plan for flood management. They have further observed that the assessment of area would change if the unit is changed to taluka/district. The RBA advised the State Govts to work out the flood prone area in a scientific manner by making use of topographic maps and detailed hydrological data. The inundation should also be linked to probabilities of recurrence interval and there must be a uniform manner of such assessment for all states. The true picture could only emerge when area prone to floods are assessed scientifically, basin wise with various probability of occurrence.

The Working Group on Flood Control Programme for the Tenth Five Year Plan (2002-07) has further observed that figures of maximum area affected (data base 1953-2000) as reported by the states are without cross check and verification. Prima facie, the figures given by some of the states are questionable and are liable to be brought downwards in any careful review. The Working Group suggested such a review before treating the figures as firm or reliable.

The Expert Group for Flood Management in the states of Uttar Pradesh and Bihar (Aug.1999) while examining the figure of area flooded reported by Bihar as 4.75 m ha. in 1987 floods, stated that updated figures are not supported by requisite details and contour maps. The Expert Group felt that in absence of requisite supporting details for any revised

estimates, the figures of "area liable to flood" as indicated in the report of the RBA (1980) may be continued to hold good until revised scientific assessment are made available by the states.

The National Commission for Integrated Water sResources Development (Sept.1999) recommended that a permanent unit should be set up by each usually flood affected state which can prepare maps and reports of flood affected areas for each flood event mentioning the flood levels reached at various critical locations and nature and quantum of damages assessed both in physical and financial terms. This unit can then check up with the help of satellite imageries and previous data, whether the assessment in the future floods (when they occur) needs to be scaled down or not.

In view of above there is strong case for adopting Scientific Approach for arriving at reliable flood affected area in the country.

Scientific Approach using Sattelite Imageries

Satellite remote sensing coupled with Geographical Information System (GIS) has a powerful role in monitoring and mapping flood inundated and drainage congested areas. Remote sensing data acquired in the visible, near infrared (IR) and short-wave infrared (SWIR) regions have shown encouraging results in providing information on spatial pattern of flood inundation. Both pre- and post-monsoon period data are required for delineation of flood inundation and flood affected areas. The flood inundation mapping through computer-assisted digital analysis approach, is based solely on their spectral response pattern as seen in the image or as portrayed in the changes in spectral radiance or brightness temperature values of space-borne multi-spectral data. This, in turn, is a cumulative effect of terrain's relief, vegetation cover, wetness, etc. In False Colour Composite (FCC), water is represented by dark blue or black colour. Colour of shallow water slightly changes from dark blue to light blue. Flooding is confined in the flood prone areas in low-lying areas, local depressions and lower element of the slope. Such areas have either standing water or a thin film of water or surface wetness during flood season while they remain almost dry during pre-monsoon seasons. The base data showing the administrative boundaries, population details, agricultural activities, important places, communication networks and other infrastructure details may be prepared well in advance of the monsoon season. The availability of satellite data may be prepared well in advance. Various satellites having sensors which operate both in optical as well as in microwave region of Electro Magnetic Spectrum at different spatial resolutions (Table 1) can be used for obtaining information regarding the availability of satellite data. The reference map of all the individual satellites are readily available and are used for identifying the path and row numbers of the satellite coverage in the area of interest. Based on the orbital calendar of the satellite, the date of pass of satellite can be known in advance (Table 2).

TABLE: 1
DETAILS OF VARIOUS SATELLITES AND SENSORS FOR MONITORING AND MAPPING OF FLOOD INUNDATION AND DRAINAGE CONGESTED AREAS

Optical/ Microwave	Satellite	Sensor	Spatial resolution in metres	Revisit period in days
Optical	IRS-1C/ 1D	LISS-III WiFS PAN	23.5 188 5.8	24 5 24
	IRS-P5	PAN	2.5	24
	IRS-P6	LISS-III AWiFS LISS-IV	23.5 56 5.8	24 5 24
	LANDSAT 6	TM	30	16
Microwave	ERS 1,2	C Band	30	16-18
	RADARSAT*	C Band System	100 (ScanSAR wide)	3 (at mid-latitudes)

- *Different resolution at different beam modes*

TABLE: 2 TYPICAL ORBITAL CALENDAR FOR IRS P6

Path																								
	167	172	177	182	187	168	173	178	183	188	169	174	179	184	189	170	175	180	185	190	171	176	181	186
	143	148	153	158	163	144	149	154	159	164	145	150	155	160	165	146	151	156	161	166	147	152	157	162
	119	124	129	134	139	120	125	130	135	140	121	126	131	136	141	122	127	132	137	142	123	128	133	138
	95	100	105	110	115	96	101	106	111	116	97	102	107	112	117	98	103	108	113	118	99	104	109	114
	71	76	81	86	91	72	77	82	87	92	73	78	83	88	93	74	79	84	89	94	75	80	85	90
	47	52	57	62	67	48	53	58	63	68	49	54	59	64	69	50	55	60	65	70	51	56	61	66
	23	28	33	38	43	24	29	34	39	44	25	30	35	40	45	26	31	36	41	46	27	32	37	42
	340	4	9	14	19	341	5	10	15	20	1	6	11	16	21	2	7	12	17	22	3	8	13	18
	316	321	326	331	336	317	322	327	332	337	318	323	328	333	338	319	324	329	334	339	320	325	330	335
	292	297	302	307	312	293	298	303	308	313	294	299	304	309	314	295	300	305	310	315	296	301	306	311
	268	273	278	283	288	269	274	279	284	289	270	275	280	285	290	271	276	281	286	291	272	277	282	287
	244	249	254	259	264	245	250	255	260	265	246	251	256	261	266	247	252	257	262	267	248	253	258	263
	220	225	230	235	240	221	226	231	236	241	222	227	232	237	242	223	228	233	238	243	224	229	234	239
	196	201	206	211	216	197	202	207	212	217	198	203	208	213	218	199	204	209	214	219	200	205	210	215
					192					193					194					195				191
Jan	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
	25	26	27	28	29	30	31																	
Feb								1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
	18	19	20	21	22	23	24	25	26	27	28	29												
Mar													1	2	3	4	5	6	7	8	9	10	11	12
	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31					
Apr																				1	2	3	4	5
	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29

With the start of monsoon, the news/information regarding the flood prone areas are closely watched. The updates from flood forecasting agencies of State and Central Government organizations should also be monitored. In case of any information regarding flooding in the area of interest, the availability of satellite data can be ascertained and the quality of data (clear and cloud free) may also be checked in the web site of National Remote Sensing Agency (NRSA) and the necessary arrangements may be formalized well in advance with NRSA to get the satellite data within 24-48 hours.

Methodology

The flood inundation mapping task basically consists of two components; task to be completed before occurrence of the flood and the works to be carried out during the flood event. To yield the useful information in real time mode, the intensive work of base map preparation, identification of control points etc should be completed well in advance. The pre flood status of the area of interest should be studied and compiled before occurrence of the flood event. During the flood, the satellite data are analyzed for identification and quantification of water spread area and GIS analysis is performed to asses the inundation statistics. The stepwise methodology for flood inundation mapping may be summarized as follows:

1. Spatial Database Generation – Before the flood event.
2. Pre-flood scenario – Before the flood event.
3. Satellite data selection – Before the flood event.
4. Flood layer generation – During the flood event.
5. Flood map composition and inundation statistics – During the flood event.

Spatial Database Generation

The digital base map of the area of interest should include the administrative boundaries (block, district, state), important roads, district headquarters and important towns, other infrastructure details etc. The control points are also identified for geo-referencing of satellite data. The features may be scanned and digitized from Survey of India toposheets, block or cadastral maps. The information collected from different sources (state departments of revenue and statistics) is referenced in a pre determined coordinate system (the process is known as geo-referencing). The map should also contain the demographic and terrain details. It is a time taking process and therefore may be planned and completed well in advance so that the spatial data base is ready before commencement of flood.

Pre-Flood Scenario

The pre-flood scenario may be delineated from satellite data and should contain the information regarding pre-flood river course, agricultural activities and other land use practice in the area. Basically, such type of information is useful in assessing the losses in the event of flooding of the area. The cloud free pre-flood satellite data in optical range are easily available and are used for crop coverage and other land use classification. Suitable techniques of classification i.e., supervised or unsupervised classification may be used for

the purpose. For crop coverage classification, Normalised Difference Vegetation Index (NDVI) has been found to be well suited. This index takes advantage of the condition where the presence of features that have higher near-infrared (NIR) reflectance and lower red light reflectance (e.g., terrestrial vegetation) are enhanced, while those with low red light reflectance and very low NIR reflectance (e.g., water) are suppressed or even eliminated. This index is calculated as follows:

$$NDVI = \frac{(NIR - RED)}{(NIR + RED)} \quad (1)$$

RED = Reflectance in Red Band

The results of this index can range from –1 to +1. Vegetated surfaces have positive values, bare soils have nearly zero values and open water features have negative values.

Satellite data selection for flood inundation mapping

During the flood season, the river water level data, flood forecasting, flood news are watched closely and during the rising trends of river, the acquisition date for satellite data are planned using orbital calendar and accordingly instructions are passed to NRSA for quick supply of data. While browsing for data if cloud free data in optical range are not available, the data in the microwave region are selected for procurement. The microwave data have the capability of cloud penetration and hence the information of water spread area may be obtained even in the presence of cloud.

Flood Layer Generation

The water bodies have a unique spectral response in the visible range when compared to the surrounding land cover. Each of the visible bands displays a unimodel histogram with no indication of a separate group of data for water pixel. The infrared band classification gives a much better representation in the water related features than do the other visible bands. This property makes the water pixel well identifiable, appearing blue to dark blue in false color composite. The supervised or unsupervised classification techniques may be adopted for its identification. The other method based on water index approach as explained below are also applied for water pixel classification. The Normalized Difference Water Index (NDWI) is calculated as follows:

$$NDWI = \frac{(GREEN - NIR)}{(GREEN + NIR)} \quad (2)$$

GREEN = Reflectance in Green Band

When this equation is used to process a multi spectral satellite image that contains a reflected visible green band and an NIR band, water features have positive values; while soil and terrestrial vegetation features have zero or negative values, owing to their typically higher reflectance of NIR than green light. Image processing software can easily be configured to delete negative values. This effectively eliminates the terrestrial vegetation and soil information and retains the open water information for analysis. The range of

NDWI is then from zero to one. Now, the modeling techniques are used to identify the water pixels. After, analyzing the spectral reflectance of water pixels an algorithm is developed and used to identify water pixels using data of different bands. The algorithm matches the signatures of a pixel with that of water and then identifies whether a pixel represents water or not. In addition, it also checks for the NDWI which is created as a separate image. In all the images, it is found that the NDWI for water is either equal to or greater than a threshold value (0.32 for Landsat TM data). The algorithm checks for the following condition for each pixel. If the condition is satisfied, then the pixel is recorded as water, otherwise not. “If the DN (Digital No.) value of NIR band of a pixel is < the DN value of the Red band and the Green band, and the NDWI is > threshold value, then it is classified as water/waterlogged, otherwise not”. The threshold value for all the satellite data likely to be used in the inundation mapping are generated from pre flood data.

Microwave image presents different grey levels related with the relative strength of the microwave energy backscattered by the landscape elements (Ulaby et al., 1982). The intensity of the backscattered signal varies according to the roughness, dielectric properties and local slope. High intensity returns appear as light tones on positive image, while low signal returns appear as dark tones on the imagery (Dautrebande et al, 1994). Flood inundation mapping using microwave data is based on the fact that water will normally appear black in a Synthetic Radar (SR) image, that is minimum radar echo (Dallemand et al., 1993). The microwave data are processed in three steps to obtain the results for flood inundation mapping. These steps consist of pre-processing of data, reduction of speckle and identification and mapping of flood inundated areas. To remove the speckle noise, which is system phenomenon and is not result of spatial variation of average reflectivity of the radar illuminated surface, two methods; Synthetic Aparture Radar (SAR) image multi-look processing and filtering techniques can be used.

Flood Map Composition and Inundation Statistics

The flood inundation map is superimposed over the district and other administrative boundaries maps in GIS environment. The other information like infrastructural details, demographic details and crop coverage may also be superimposed over the inundation map to assess the losses due to flooding. The statistical analysis may be performed to estimate the % of district area affected by flooding, population affected, agricultural losses, damage to roads/ rails and other infrastructure etc.

Working approach for flood inundation in Bihar

The coverage of satellite data required for mapping the flooding in Bihar are determined using a NRSA utility software “SDSU’. The coverage for IRS-1C satellite and sensors are shown in Figure 1 (a) and (b). The coverage are same for IRS-1D and IRS-P6. The base showing the district boundaries are prepared from SOI toposheets/ cadastral maps etc. as shown in Fig. 2. The flood inundation derived from IRS 1D LISS III imagery of 15 Sept. 2001 covering part of districts of Vaishali, Samastipur, Khagaria, Nalanda, Nawada, Patna, Munger and Begusarai is shown in Figure 3. The flood inundation statistics derived from these data are shown in Table 3.

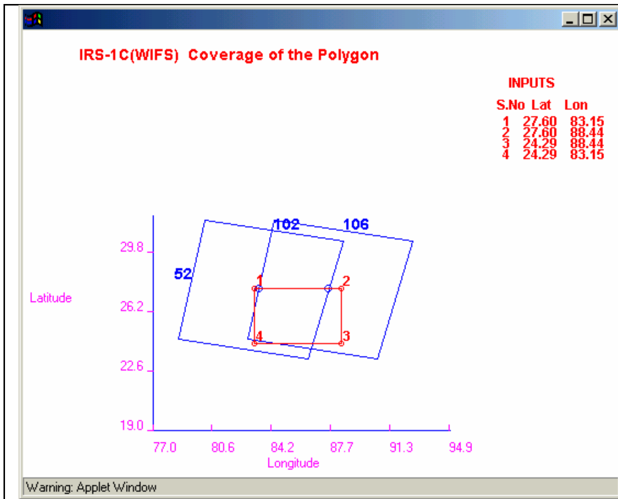

Fig.1(a) SATELLITE COVERAGE OF BIHAR WITH WIFS SENSOR

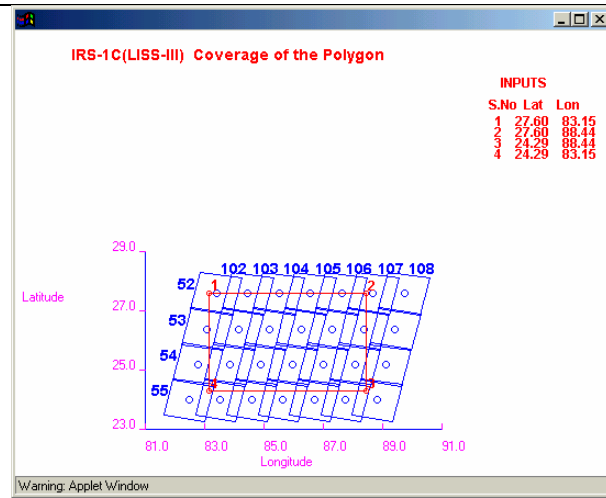

Fig.1(b) SATELLITE COVERAGE OF BIHAR WITH LISS III SENSOR

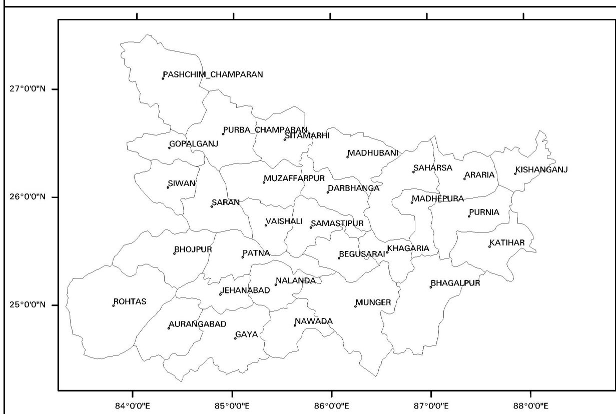

Fig.2 BASE MAPS OF BIHAR SHOWING DISTRICT BOUNDARIES

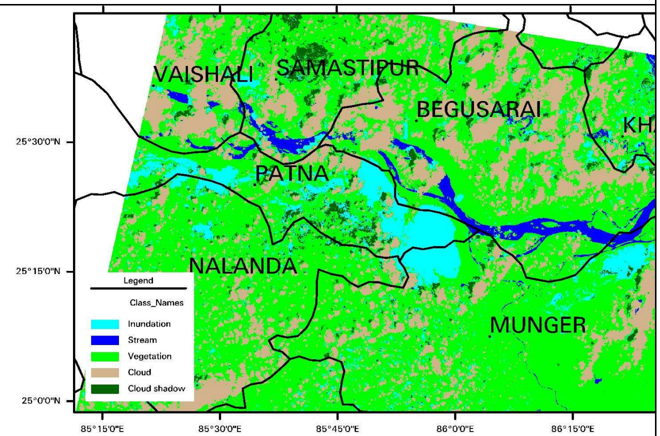

Fig.3 CLASSIFIED SATELLITE DATA OVERLAYED OVER THE DISTRICT MAP OF BIHAR.

TABLE: 3 FLOOD INUNDATION AREA STATISTICS

Sl	Name of district	Area (Ha)	Satellite Derived (IRS 1D L3, 15 Sept. 2001)	
			Inundated Area in Ha	Percent of Area Inundated
1	Vaishali	203273	0	0
2	Samastipur	247375	1560	0.6
3	Begusarai	215001	2575	1.2
4	Patna	316188	22756	7.2
5	Khagaria	165184	0	0
6	Nalanda	229348	728	0.3
7	Munger	623926	5796	0.9

Note: This is only a representative example illustrating the use of remote sensing data for flood delineation at district level. The illustration demonstrates the coverage of one scene of IRS 1D L3 data of 15 Sept. 2001 partially covering few districts of Bihar.

Damage Assessment Using Satellite Imageries

For assessing the damage caused by flood, pre and post flood scenario is compared by superimposing the inundation map over the pre-flood scenario for damage assessment. For such an assessment, the pre-flood scenario is prepared from the pre-monsoon satellite data. The images are classified for extracting information like; roads, railways, bridges, embankments and other infrastructures details. The crop coverage just before the flood is also extracted from the satellite data. The recent demographic information from the census records is linked with the base map containing the block/village boundaries. During flood, the inundation map is superimposed over these maps to assess the extent of damages to crops, infrastructures etc. The population affected by the flood may also be identified at blocks/village level and rehabilitation measures may be planned accordingly for quick and immediate relief.

The above approach would help in disbursement of Flood Relief to different States on a realistic basis.

Flood Prone Area Development Programme of Planning Commission

Govt. of India proposes to launch Flood Prone Area Development Programme in flood prone districts of the country in XI Plan. A committee headed by Chairman, GFCC was constituted by Ministry of WR, for identification & categorization of Flood Prone districts in the whole country. The committee reportedly faced lot of difficulties in reconciling the flood data supplied by various states based on information provided by Revenue Authorities. The recommended for launching of a special Plan Scheme during XI Plan for scientifically working out the flood affected areas in different districts of the country, as the figures supplied by various states could not be entirely relied upon.

Conclusions

- Flood Prone Area/area liable to floods remains almost constant as it is based on maximum value of area flooded in the past record and does’nt take into account the benefits occurred from flood management measures. It is recommended to adopt actual area flooded during the last say 10 years as the key element in providing for flood management measures.
- Remote Sensing Techniques using Satellite Imageries is most reliable and scientific method in evaluation of flood affected area and the damages.
- As the flood affected figures supplied by Revenue Authorities through State Government can’t be totally relied upon, any analysis based on such data may lead to benefits of the Flood Prone Area Development Programme not reaching the needy and targeted population affected by floods.

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