

Geographic Information System and Remote Sensing Applications in Flood Hazards Management: A Review

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Abstract: The purpose of this study is to examine and review the various applications of GIS and remote sensing tools in flood disaster management as opposed to the conventional means of recording the hydrological parameters, which in many cases failed to capture an extreme event. In the recent years, GIS along with remote sensing has become the key tools in flood disaster monitoring and management. Advancement particularly in the area of remote sensing application has developed gradually from optical remote sensing to microwave or radar remote sensing, which has proved a profound capability of penetrating a clouded sky and provided all weather capabilities compared to the later (optical remote sensing) in flood monitoring, mapping, and management. The main concern here is delineation of flood prone areas and development of flood hazard maps indicating the risk areas likely to be inundated by significant flooding along with the damageable objects maps for the flood susceptible areas. Actually, flood depth is always considered to be the basic aspect in flood hazard mapping, and therefore in determining or estimating the flood depth, a Digital Elevation Model data (DEM) is considered to be the most appropriate means of determining the flood depth from a remotely sensed data or hydrological data. Accuracy of flood depth estimation depends mainly on the resolution of the DEM data in a flat terrain and in the regions that experiences monsoon seasons such as the developing countries of Asia where there is a high dependence on agriculture, which made any effort for flood estimation or flood hazard mapping difficult due to poor availability of high resolution DEM. More so the idea of Web-based GIS is gradually becoming a reality, which plays an important role in the flood hazard management. Therefore, this paper provides a review of applications of GIS and remote sensing technology in flood disaster monitoring and management.

Key words: Digital elevation model, flood hazard management, hazard mapping, web-based GIS

INTRODUCTION

Flood catastrophe is considered to be the most costly, devastating, broad extent and frequent because of the tremendous fatalities, injuries, property damage, economic and social disruption it causes to the humankind. It has a special place when it comes to natural hazards and it actually accounts for 31% of economic losses emerging from natural hazards. In most of the developing countries, especially those in the sphere of monsoon, experiences river flooding as a frequent natural trend. Floods such as the flash-flood, which emerges from heavy and persistent rainfall within a very short time frame damages infrastructure, agricultural commodities, displace people, animals, aquatic lives, and as well causes the reservoirs and dams capacity limits to exceed as a result of siltation. Globally in the recent events, river flooding has been a major natural catastrophe, for

example, Easter in the UK in 1998, Eastern Europe in 1998 and 1999, China in 1998, and Venezuela in 1999 (Saders and Tabuchi, 2000). The South China flood of 1998 took over four months, in which twenty million people were heavily disrupted in their socio-economic lives, thousands of inhabitants died and caused a physical loss and damage, which was estimated to cost twenty billion US Dollars (Turkey Contractors Union, 1998). The first step in formulating any strategy that has to do with flood management is by identifying those areas that are likely to be most susceptible to flooding, which is even the most difficult step for the developing countries especially those in the monsoon realm because the funding available for developmental activities is quite limited. With the conventional tools fixed presently at various river gauging stations it is most often very rare or difficult in recording an extreme event of flood with a very high return period. Any flood prediction or risk

model been tested in the developed nations failed in the developing countries due to the lack of sufficient ground data, because the density of the gauging stations in the developing nations is quite low. So, what is now the panacea? GIS and remote sensing has been reliable tools and been used in the evaluation of geo-environmental catastrophes by providing a sort of synoptic coverage of a very broad area in a cost effective way, which overcomes the bottle-neck and limitations cause by the conventional ground stations in recording an extreme hydrological information during an extreme event. Moreover, the remote sensing tools provide the researcher with a sort of multi-date satellite imageries, which in turn aids the researcher in monitoring and recording the change progress of the past flood events. In the recent years, development in the areas of GIS and remote sensing has been embedded into the assessment of geo-environmental catastrophes, which profoundly facilitated advancement of flood susceptibility mapping, flood risk assessment, and flood management. It is evident that flood related problems could be solved through planning studies and also through a detailed project in the floodplain areas. GIS systems are built to cover a wide range of applications and are designed to integrate a vast variety of environmental data, allowing them to work together in a readily accessible way (Al-Sabhan *et al.*, 2003). Moreover, it is evident that because of the multi-dimensional nature of the natural disasters, GIS has a profound role to play (Coppock, 1995). Hausmann (1988) and Clark (1998) stated that the key purpose of using GIS in the management of flood is not only for visualization purposes of flood extent, but it also creates some potentials to further analyze this product in order to quantify likely damages cause by flood.

Since 1997 when Smith review the application of remote sensing in detecting river inundation, stage, and discharge, the focus is changing from flood boundary delineation to flood risk and damage assessment. Hence, there is a need to actually review the current studies carried out using GIS and remote sensing technology in flood management as a whole with special reference to various prospects and shortcomings encountered in the process of application. This study presents some recent advancement on delineation of flooded areas and flood catastrophic mapping using the GIS and remote sensing technology with special reference to issues associated with the use of these tools in combating floods in extremely flat flood plains of monsoon.

The purposes of this review are:

- To spotlight the advancement of GIS and remote sensing as tools used in flood delineation and management
- To spotlight some of the shortcomings faced when using the GIS and remote sensing technology especially due lack of having high satellite resolution

images in most situations. These will in turn serve as a guide to the researchers as well as the planning authorities for future preparations.

FLOOD AREAS DELINEATION USING REMOTE SENSING TOOL

Generally, the roles of experts in natural hazards management are monitoring a situation, simulating a sophisticated natural phenomenon as accurate as possible so as to aid in coming up with better, accurate, and precise forecasting models, contingency plans that are quite suitable, and preparation of a spatial databases (Kundzewicz *et al.*, 1993; Lanza and Conti, 1994; Sabins, 1986). Therefore, from the inherent characteristics, namely, spatial continuity, uniform accuracy and precision, multi-temporal coverage and complete coverage regardless of site location, the remotely sensed data can be used very much effectively.

The Federal Emergency Management Agency (FEMA) of the United States of America stated that floods are the second most common and widespread of all natural catastrophes. Averagely, more than 225 populace are destroyed together with properties that worth more than 3.5 billion US dollar are smashed up by intense rain and flooding annually (<http://www.fema.gov/library>). Studies has been carried out using valuable hours and resources by scientists and researchers in quest for better techniques when it comes to flood forecasting, flood depth and extent delineation. Hence, satellite imageries are found and proved to be the most successful and valuable tools for flood management especially when it comes to detail mapping needed for the development of risk assessment maps and for inputting different categories of hydrological models; developing a larger scale view of the general flood situation within a river catchments or coastal belt with the aim of identifying areas that are likely to be at greatest risk and in the need of immediate assistance; and monitoring land use/cover changes yearly in order to quantify major changes in the land use/cover as a whole, particularly extent of impervious area/ surfaces.

OPTICAL REMOTE SENSING TOOLS FOR FLOOD AREAS DELINEATION AND MANAGEMENT

In the last decades, the available remote sensing data were from LANDSAT Multi Spectral Scanner (MSS) with a resolution of eighty meters. The program of the LANDSAT is the long lasting running activity in gathering multi-spectral digital data of the surface of the earth from the space. Remote sensing from satellite vehicles has become progressively more important right from the very first time when the LANDSAT 1 satellite (formerly ERTS-1) was successfully launched. As

Table 1: Characteristics of LANDSAT Sensors

Sensor ^{a/}	Landsat platform	Spectral bands and range (µm)		Altitude (Km)	Resolution (m)	Image size (Km)	Coverage repeat
RBV	1,2,3	PAN	0.505-0.750	920	79x59 ^{d/}	185x185 ^{d/}	
		1b/	0.47-0.575		30x30 ^{e/}	99x99 ^{e/}	
		2c/	0.580-0.680				
MSS	1,2,3,4,5	3c/	0.690-0.830	920 ^{f/} 705 ^{h/}	79x57 ^{g/}	185x185 ^{f/}	every 16 days ^{f/}
		4(green)	0.5-0.6 ^{f./}		60x60 ^{h/}	185x170 ^{g/}	every 16 days ^{h/}
		5(red)	0.6-0.7		237x237 ^{i/}		
		6(near IR)	0.7-0.8				
		7(near IR)	0.8-1.1				
TM	4,5	8(thermal)	10.4-12.6 ^{h/}	705	28.5x237 ^{i/}	85x170	every 16 days
			10.45-0.52		120x120 ^{v/}		
		2	0.52-0.60				
		3	0.63-0.69				
		4	0.76-0.90				
		5	1.55-1.75				
		6	10.40-12.50 ^{i/}				
7	2.08-2.3						

The Table 1 illustrates the synoptic characteristics of the Landsat Multi-Spectral Scanner and other Landsat sensors, Primer on Natural Hazard Management in Integrated Regional Development Planning

LANDSAT 1 (then the Earth Resources Technology Satellite) was commissioned on July 23, 1972, data is being compiled in an incessant flow, through one by one launch of LANDSAT (LANDSAT 7 was the latest in orbit), along a near vertical path as the satellite moves from north to south. LANDSAT path designations amplified from east to the west. Since from that time several satellites comprising remote sensing capabilities have been invented and adopted successfully. The coverage of the Landsat Multi Spectral Scanner (MSS) exists since from 1972 in four spectral bands with 80 meters resolution. Similarly, band 7 (0.8-1.1 µm) has been discovered to be particularly appropriate in distinguishing water or wet earth surface from dry earth surface because of its powerful absorption of water into the near infrared range of the spectrum (Smith, 1997). The first practical imagery in four different spectral bands from the space was successfully presented by the Landsat Multi-Spectral Scanner (MSS). Table 1 illustrated the synoptic characteristics of the Landsat Multi-Spectral Scanner and other Landsat sensors. But scientists and planners never noticed the accompanying Return Beam Vidicon (RBV) sensor on this and subsequent satellites of this series like the MSS. The Landsat sensors and other subsequent ones broad aerial coverage, with their ability of processing the sensor's data in a digital format, actually made the satellite-derived data helpful to district planners and other experts concerned in natural hazard assessments. The Earth's surface is scanned from west to the east by the Multi Scanner System sensor as the satellite navigates in its downward (North-South) orbit above the sunlit or sunny side of the Earth. There exist six detectors for each spectral band, which present six scan lines on every active scan. Global coverage needed for studying land surface changes is produce through the combination of scanning geometry, satellite orbit, and the Earth rotation. There

exist numerous ground stations to record LANDSAT data globally (www.geoimage.com.au, and ltpwww.gsfc.nasa.gov). The very first investigations as regards to flood control with the aid of remote sensing tools as well as its data were mostly concentrated on the flood prone regions of the United States. Multi Spectral Scanner data were utilized in dealing with the flood catastrophe of Iowa (Hallberg *et al.*, 1973; Rango, 1974), Arizona (Morrison, 1973), and the River basin of Mississippi (Deutsch *et al.*, 1973; Deutsch and Ruggles, 1974; Rango, 1974; McGinnis and Rango, 1975; Morrison, 1976). The dry land surfaces because it is more or less Landsat Thematic Mapper (TM) was initially introduced in 1982 on the Landsat 4, comprising seven spectral bands in which six out of them has a 30m resolution and one in the thermal IR range with 120 m resolution. The Landsat Thematic Mapper with 30 m imageries resolution has become the major source of data for monitoring flood and flood inundation boundary delineation in the early 1980s. Landsat TM band 4 also proved to be very useful in differentiating water surfaces from equivalent of MSS band 7. But the great bottleneck of the Landsat Thematic Mapper (TM) Near Infrared (NIR) band is that it proved to be extremely difficult or in many cases even unfeasible to be utilized in a developed or built-up land uses such as densely or slightly populated residential, commercial, and industrial areas. This is because the NIR reflects only a very minute energy from asphalt areas, which appears black in the imageries. Hence, this actually makes it easier to confuse the built-up areas with the available water bodies. On the other hand, this setback was effectively tackled by Wang *et al.* (2002) where they added the Landsat TM band 7 to the NIR (band 4) band in an effort to delineate the inundated areas. Moreover, the reflectance from water, paved road surfaces, and roof tops differ significantly in the Thematic

Table 2: Characteristics of SPOT sensors

Band	Wave length (μm)	Resolution(m)	Image format
Spot sensor: Multispectral High Resolution Visible (HRV)			
XS1	0.50-0.59	20	60 Km Swath with vertical
XS2	0.61-0.68	20	Viewing angle and up to
XS3	0.79-0.89	20	80Km With+/.27 viewing angle from vertical
Spot sensor: Panchromatic High Resolution Visible (HRV.P)			
P	0.51-0.73	10	60Km Swath with vertical viewing angle and up to 80Km With+/.27 Viewing angle from vertical

The Table 2 illustrates the synoptic characteristics of the SPOT sensors: Multi-Spectral High Resolution Visible (HRV), Primer on Natural Hazard Management in Integrated Regional Development Planning

Mapper (TM) band 7 (2.08-2.35 μm) images. Therefore in the band 4+band 7 images, selecting the density slice for extracting the flood water becomes extremely easier. But by mere simple density slice or supervised classification is not sufficient to identify the inundated areas correctly in some cases. So, an exceptional concentration was given in dealing with specifically a monsoon flooding in the developing countries like West Africa (Berg and Gregiore, 1983), India (Bhavsar, 1984) and Thailand (Ruangsiri *et al.*, 1984).

In the later stages, the imageries of SPOT multi spectral were also used for flood delineation with an assumption that water has very little reflectance in the near infrared segment of the spectra. The SPOT 1, which is the first French satellite, was invented with the Sweden and Belgium collaboration launched in 1986. In 1990, the SPOT 2, 3 and 4 were developed and launched, 1993 and 1998 respectively. Subsequently, SPOT 5 was also launched in Oct, 2001 to guarantee stability of service. SPOT satellite with its High Resolution Visible (HRV) sensors in many cases is similar with the Landsat MSS and TM sensors. HRV multi spectral sensor (XS) ranges from the green wavelength into the NIR. Its coverage is in three spectral bands rather than the four spectral bands usually found in the MSS, but with much greater spatial resolution (20 m versus 80 m), even though it covers only about 1/9 of the area capable of being covered by a Landsat scene. Furthermore, panchromatic sensor (HRV-P) is included in the SPOT, which cover ups the green through red portions of the visible spectrum in a particular band with 10m resolution. Sixty kilometers swath along the orbit path is covered both by the HRV sensors. It is hence quite possible to acquire concurrent side-by-side coverage from each and every sensor, creating a 117km swath width, though this potentiality has not been often used. For instance, SPOT imageries were used together with a Digital Elevation Model in delineation of the monsoon flood in Bangladesh (Brouder, 1994; Oberstadler *et al.*, 1997; Profeiti and MacIntosh, 1997; Sado and Islam, 1997). Moreover, resolution of imageries that are coarse such as Advanced Very High Resolution Radiometer Radiometer (AVHRR) data has also been found helpful for floods of a regional aspect (Wiesnet *et al.*, 1994; Huh *et al.*, 1985a, b, c; Islam *et al.*, 2000a, b, c, 2001, 2002). Even though AVHRR imageries are

coarse when it comes to resolution and normally tainted by cloud coat; their good point lies in their high temporal resolution. This actual benefit enables one to scrutinize the persistent growth of a flood in near real-time.

In order to make use of the ability of the near infrared band more successfully in discovering water, a Normalized Difference Vegetation Index (NDVI) can be adopted appropriately to examine river flood from AVHRR imagery. Water is well known to have a unique spectral mark in the near infrared, which makes it entirely different from rest of the surface features. Consequently, whenever a surface feature is found to be inundated its NDVI value alters noticeably from the usual condition. It has been observed by Wang *et al.* (2002) that in the lower reaches of the Yangtze River, the NDVI value for flooded surface features stays negative whilst the value for non flooded surfaces is normally larger than 0. However selection of this threshold is quite dangerous for the reason that natural situation of river inundating differs very much from one place to the other. Therefore, the actual difficulties of selecting a fitting threshold emanated from two actual facts. At the outset, the albedo of water bodies amplifies drastically because of the high concentration of sediments in the inundated water. Secondly, albedo of exposed soil diminishes significantly because of its high moisture substance during the period of the monsoon term. Hence, these two issues jointly lessen the distinction in NDVI value between flooded and desiccated surfaces. Similarly, based on a number of studies, NDVI values of inundated water were found to be considerably positive (Barton and Bathols, 1989). Thus, a straight forward approach of using simple NDVI values may not be generally efficient in mapping of flooded areas. Likewise, several other issues like atmospheric state, cloud coat and satellite viewing angle as well influence NDVI values and as a result, efforts ought to be made to reduce these effects before calculating the NDVI.

MICROWAVE REMOTE SENSING TOOLS FOR FLOOD AREAS DELINEATION AND MANAGEMENT

The advancement of the microwave radiometers remote sensing has shown a profound promise because of the direct contact between hydrometeor and the radiation

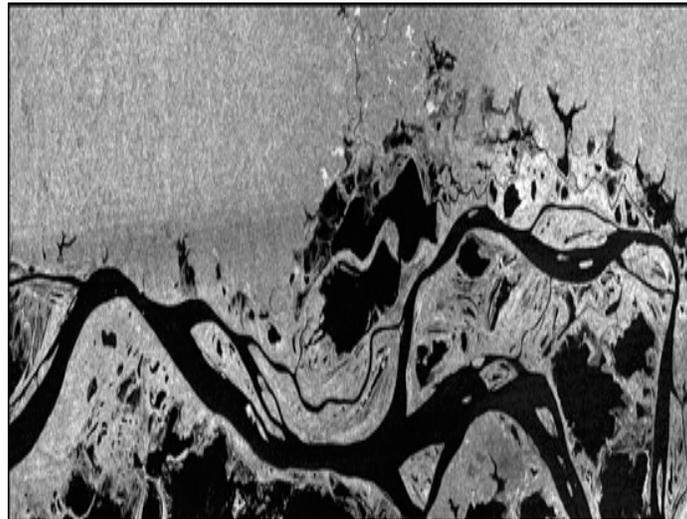


Fig. 1: Lago Grande, Brazil, showing flood delineation (<http://www.space.gc.ca>). The figure above illustrates excellent land/water delineation. It is the forest adjacent to Lago Grande in Brazil, which experienced a seasonal flooding. The forested areas are of a lighter tone on this image and the dark areas represent the high water mark and flooded areas

field as opposed to the infrared measurements (Faisal *et al.*, 2004), which are only sensitive to the topmost layer of the cloud. The existence of cloud cover appears as the only most imperative hindrance in capturing the progress of floods in awful weather situation (Rango, 1977; Lowry *et al.*, 1981; Imhoff *et al.*, 1987; Rashid and Pramanik, 1993; Melack *et al.*, 1994). The microwave radiation has the ability of piercing a clouded sky and offering an insight into the structure of rainfall itself. At present the most familiar approach to inundation management is to use Synthetic Aperture Radar (SAR) imagery and optical remote sensing imagery concurrently in one project (Honda *et al.*, 1997; Liu *et al.*, 1999; Chen *et al.*, 1999).

Canadian satellite uses the SAR sensor, which is an onboard ERS and RADARSAT satellite. The SAR allows a 24 h data gathering, which is autonomous of weather situations and lightening. It has careful viewing angles allowing a broad range of topographical situations, applications and entire requirements of the land coverage to be contained and it as well have the capability to clearly differentiate between the land and water. SAR is capable of providing images both in the day or night time, in spite of any predicament such haze, snow, light rain, smoke or clouds. Hence, in a humid temperate climatic setting, the SAR is the most appropriate tool for flood delineation and monitoring. Moreover, this sensor has the ability of detecting open water surfaces, near surface moisture, soil moisture changes, the degree of wet snow packs as well as capability to differentiate between wet snow and dry snow and between wet soil and dry soil. According to Hillard *et al.* (1999), using appropriate imagery can make it achievable to generate a series of

snow cover maps over the time of the snowmelt period to approximately enumerate the rate of snowmelt in the catchments. Fine, Standard, Wide, ScanSAR (narrow and wide), and Extended Beam (high and low incidence angles) are the imaging modes of RADARSAT. The radar remote sensing proved to be the most efficient and effective tool when it comes to detecting oil seeps and flood damages. It has been reported that over 500 million USD in dry holes have been avoided because of the detection of the oil seeps by the radar satellite sensor. Figure 1 illustrates excellent land/water delineation. The forest adjacent to Lago Grande, Brazil experience seasonal flooding. The forested areas are of a lighter tone on this image and the dark areas represent the high water mark and flooded areas.

There is what is called thresholding, which is one of the more often used methods in an active remote sensing used in separating an inundated land and non inundated land in a radar image (Liu *et al.*, 1999; Townsend and Walsh, 1998; Brivio *et al.*, 2002). Usually, a threshold value of radar back scatter is place in decibel and subsequent by a binary algorithm to verify whether a given cell in a raster is inundated or not. Radar backscatter is calculated as a function of the incidence angle of the sensor and digital figure (DN) (Chen *et al.*, 1999). Based on the study area and the entire spectral signature of the imagery, the threshold values can be determined by a number of processes. For a powerful tool to identify inundated area in SAR imagery, change detection can be utilized based on coherence and amplitude change detection techniques extensively used in SAR realm. This is by obtaining two images captured

prior to the flood incidence and after the flood incidence. Areas are predicted to be flooded where the radar backscatter is noticed to be in substantially turning down from before and after flood images in the amplitude approach, whilst in the coherence approach areas are usually recognized to be flooded where the coherence or correlation of the radar backscatters from before and after flood images are extremely low (Nico *et al.*, 2000). The same region's multi-date SAR scenes can be projected to red, green and blue channels in producing a color composite. Three ERS SAR scenes were utilized by Long and Trong (2001) in generating this sort of composite picture. Progress of an inundation during a particular time period was successfully depicted by the composite image. This particular technique is quite easy and straightforward to carry out and it gives a chance to readily detect those areas that remains water logged for a maximum time period.

On the other hand, using the SAR imageries also have some accompanied shortcomings in which flooded area is extracted inaccurately. One of the key problems is the correlation that exists between the radar wave length and the roughness of the topography and water body, because still and clean water works as a reflector to the radar signals. As a result, the radar antenna receives no backscatter, which in turn the water appears in dark tenor in the SAR imageries. The appearance of the rough water surface in SAR imageries is brighter than the appearance of the calm water (Yang *et al.*, 1999). A bad and windy situation usually exists over the affected region during floods. Wind aggravates undulations in the water surfaces, which often produces problem for the analyst to determine the threshold value when delineating the flooded area.

Likewise, Hess *et al.* (1990) added that forest cover causes an impediment to correctly detect the inundated areas from a SAR image. Kundus *et al.* (2001) stated that the key to detect the flooded regions beneath the forest cover lies in the fact that inundated forests creates a light radar backscatter in contrast to non inundated forests because of the dual bounce effect, but the inundated regions with no forest cover come out dark in SAR imageries. Pope *et al.* (1997) added that the swamped forests replicate 2dB as radar backscatter in the L-band. Therefore, this specific attribute has been employed in detaching the flooded areas from the non flooded ones by adopting the thresholding method (Rosenqvist *et al.*, 2002). It is also quite problematic to accurately segregate the inundated settlements and non-inundated settlements. Usually the building heights backscatter covers the flood water backscatter within a settlement. This is very typical in the rural areas where the houses are mostly enclosed by tall trees such as settlements of the monsoon Asia. Because of the effect of these trees, flood surrounded by these settlements is not easy to notice (Oberstadler *et al.*, 1997).

The setting up of a worldwide threshold value for detection of flood is not acceptable yet, because the kind of algorithm to be adopted in distinguishing a wet land might not be applicable to that of dry land. DMPS SSM/I (Specific Sensor Microwave/Imager) data was used by Jin (1999) regarding the use of an algorithm as mentioned above. He came to a conclusion that a particular algorithm formed on the basis of a wet land situation creates false outcome for flooded regions beneath a forest cover. In addition, Jin further highlighted concerning the need to acquire knowledge related to regional geography of an area under examination for the effectiveness of setting any threshold value. Furthermore, to influence the interpreter's capability in separating flood areas from the non-flood edonesunderneath forest cover, integration of wave length, incidence angle and polarization plays a key role. The ratio of backscatter from inundated forests to the non-inundated forests is greater in horizontal polarization than at vertical polarization when the same wave length and incidence angle are set. Wang *et al.* (1995) added that as the wave length and polarization parameters are constant, the abovementioned ratio is greater under a small incidence angle than large incidence angle. The backscatter of radar solely relies on the rough surface's orientation such as furrows of a ploughed field. Incidence angle of radar and the resultant difference in backscatter likewise create impediment when it comes to flood areas delineation from SAR imageries. Conclusively, utilizing forested region's imageries captured at a lower incidence angle attested to be more helpful than those imageries captured at a higher incidence angle. It has been recommended by Townsend and Walsh (1998) that the use of Japanese Earth Resources Satellite Synthetic Aperture Radar (JERS SAR) imageries to European Remote Sensing satellite (ERS) for detection of inundated regions underneath a forest cover is better because of the lesser incidence angle of the previous as compared to the last. The Japanese Earth Resources Satellite proved to have some advantages compared to other earth observation satellite systems in identifying floods below a forest canopy because the L-Band signal of JERS1 is mainly sensitive to stagnant water under the forest cover (Rosenqvist *et al.*, 2002). On the other hand, Radar-sat SAR imageries are also better to ERS when it comes to flood mapping because the Radar-sat can revolve its sensor distributing the radar signal at different incidence angles. Andre *et al.* (2002) further added that this manipulating ability proves to be quite helpful in locating the inundation affected areas in different types of land cover and terrain.

THE INTEGRATION OF OPTICAL AND MICROWAVE REMOTE SENSING IN FLOOD HAZARD MANAGEMENT

Efforts regarding flood mapping has created some advantages over the use of both optical and microwave

remote sensing technologies for better results in the recent years, which in several occasions help in coming up with a better flood management policy. Features that only appear bright are mountains and slopes situated perpendicular to the radar beam whilst all the remaining areas appear to be dark or shaded. This actually causes a hindrance to effectively detect the mountains flooded areas, because as a result of the shaded appearance it is going to be very easy to mistakenly identify the mountainous areas as flooded instead of the real flooded areas. Yang *et al.* (1999) proffered a way out to this impediment by fusing Landsat TM imageries with SAR imageries. The mountain regions will be extracted from the Landsat TM data and overlaid on the SAR images. Section detected as a mountainous area in the TM image was eliminated from the SAR imagery in order to get rid of the falsely segregated inundated areas in the SAR imagery. Hence, this technique resulted to exact demarcation of the flooded areas. Though, the authors came to realize a predicament that the implementation of this technique may end up in removing some water bodies that are in existence from the real hydrological layer of the mountainous region. In order to fix this inaccuracy, the data from TM was consulted and later on the water bodies within the mountainous regions were brought back in the last output. Hence, this particular manuscript shows that the technique of using data taken by different sensors will not yield a direct and accurate solution, which often needs iterative trial in order to help in achieving the best outcome.

Similarly, Tholey *et al.* (1997) added that the usefulness of creating land cover maps is realized to be quite imperative because it offers information regarding the stable water bodies' in a common hydrological circumstances and in turn helps by keeping the analyst afar from all likely confusion of counting the permanent water bodies as flooded area. However, in the case of tackling the issues of flooding in the monsoon regions, one ought to consult the images of a wet or rain period in order to cut out the existing natural drainages. According to Islam *et al.* (2002), failure to make use of those images captured in wet season would lead to underestimation of the existing natural drainage, which consequently would lead to an overestimation of the inundated areas. The vital aim and efforts of delineating the flooded area is purposely to assess the impact of flood on the economy of the people and their livelihood as a whole. For assessing the extent of destruction on various sorts of land uses, land use maps obtained first and foremost from optical remote sensing are overlaid on the flood maps. Actually, in estimating flood risk, different land use categorization approaches have been used by researchers. Islam *et al.* (2001) stated that predominantly, most of the research papers analysis discussed on the classification of land use pattern of the flood prone regions into conventional classes such as urban area, cropland, barren land etc,

though this kind of classifications do not most selectively give out the purpose. Therefore, a more thorough classification of the economically concentrated land use is recommended since damage imposed over high valued land use areas is of better concern, a more comprehensive classification is recommended for the economically concentrated land uses. According to Honda *et al.* (1997), the aforementioned can be achieved significantly by amalgamating the low valued land uses such as forest area, infertile land, swampy land into a single class and applying a thorough categorization of urban areas and arable land. Joy Sanyal (2004) added and recommended that it is understood that there is a profound need to create a data archive for the developing countries mainly for selected satellites. The archive would help in portraying the study area's background land cover situation for different seasons and in turn ease the change detection process. Remote sensing of flooded areas can just become a helpful instrument in flood management and alleviation with such type of data set.

Flood catastrophe management using GIS: GIS has become a promising and great instrument adopted in the management of flood hazard as well as in risk areas assessment based on a given geographical location. Consequently, its profound capability made it possible to produce a flood hazard map by delineating the flood prone areas. This kind of map will help the responsible authorities to quickly assess the potential impact of the flood disaster and take appropriate control measures to curtail the foreseen flood disastrous impact. GIS provides a broad range of tools for determining areas affected by floods or predicting areas that are likely to be inundated by significant flooding. In addition, GIS is such a tool that can aid the planning authorities and the floodplain managers in detecting and delineating flood prone areas in a given community. It also facilitates geographical information storage in a database that can be queried and displayed graphically for analysis. Flood prone zones can be detected and aimed for alleviation measures or stringent floodplain management practices through the overlay or intersection methods of various geographical layers. Safie *et al.* (2006) conducted a study using GIS for flood hazard mapping in Segamat, Johor Bahru in the Western Malaysia. Data used were originally produced by Directorate of National Mapping Malaysia (JUPEM) such as the topographical map series L7030 at scale 1:50 000 with 20 m contour intervals. Other data such as the geological map, utilities, and land use were as well obtained from Johor Structure Plan Studies 2002. The authors used two different softwares; namely, Autocad Map 2004 and ArcView 3.1. The data preparation, processing and editing were done using the Autocad, which was later converted to GIS format for (2009) simulating flood water of Damansara River,

Selangor. In doing the simulation, the focus was on the time of water filling as well as flood volume discharge (m^3/n) over the floodplain. Their result of analysis illustrated that the time travel for the flood water to reach the crest level of 1.23 m is just an hour 30 min. When converted to flood volume is approximately $100 m^3/n$ covers an area of 107 ha of flood area approximately. Conclusively, the hydrograph shows that the time travel to rise is just 30 min, where it demonstrated the benefit of the incorporation between the GIS tools of the ArcView and XP-SWMM as hydraulic software in developing a flood hazard mapping for urban area in the study area.

Some shortcomings of gis application in flood hazard management: The purpose of flood hazard management is to provide a viable preventive mechanism to immensely reduce if not to eliminate the negative consequences of the flood disasters. Unfortunately, this requirement is not most of the time achieved by GIS and its model. Albrecht *et al.* (1997) spotlighted that the conventional GIS applications has been hampered by several key obstacle such as user interfacing, data integration, presentation of dynamic processes in GIS and cartographic modeling language (Map Algebra). GIS structures are created in such a way to cover a broad series of applications and are designed to incorporate numerous environmental data, letting them to work jointly in a readily reachable way (Al-Sabhan *et al.*, 2003). Consequently, fundamental GIS functionality for modeling still needs somewhat intricate software and hardware, which in turn causes significant operating costs. Integration of simulation models is one more issue to be considered as well as essential tools in environmental applications of computer know-how, which has the ability to drastically advance the potential of GIS for environmental simulation and understanding. Burrough (1997) added that this multifaceted incorporation needs a major programming effort and data management. Therefore, there is an ultimate need for Web-based GIS, though it is becoming a reality. This will serve as an interface to benefits the users, authorities and the local communities in accessing information easily and offering technological transparency, platform independence, visual interaction with data, multimedia environment, and cost efficiency. This would similarly help the local communities to participate in the environmental decisions that affect them directly.

Flood catastrophe and risk areas delineation using gis and remote sensing tools: Flood is a natural calamity and its risk is described in terms of hundred-year flood (Godschalk, 1991). One of the main issues in flood management is the ability to prepare a reliable hazard map by identifying those areas having greater flood hazard likelihood. Normally, flood mapping is achieved by

overlaying a pre-flood imagery and peak flood imagery in order to demarcate the flooded area (Nirupama and Simonovic, 2002). With the help of the existing land use base map, damages regarding properties and crops are assessed (Colby *et al.*, 1999; Brakenridge *et al.*, 1998; Nico *et al.*, 2000; Saders and Tabuchi, 2000). Nico *et al.* (2000) applied amplitude change detection method using multipass SAR data in detecting flooded area. On the other hand, both the aforesaid techniques only allows inundated regions to be detected when they are inundated at the time of the second satellite pass and not at the time of the first one (Nirupama and Simonovic, 2002). Nirupama and Simonovic (2002) further elaborated that coherence (two waves are believed to be in coherence if their crests and troughs assemble at the same position and at the same point in time) resulting from multipass interferometry data can be adopted instead, as a sign of changes in the electromagnetic scattering behavior of the surface, therefore potentially depicting all the regions affected by the overflow incident at any time between the two passes.

In the year 1993, three different methods for hazard zoning were introduced by Rejesk. The first one explains a binary model assessing whether there is hazard or not in a particular raster cell. Second involves ranking various places of a given region based on the amount of the hazard present. Third, which is the last approach; a number of hazard values were allocated to every raster cell based on the outcome of a multivariate model which was developed on a host of criteria connected to river flooding and associated hazards, and this was later condemned by Wadge *et al.* (1993).

Preparation of the flood risk maps actually depends on the estimated depth of the flood, which is usually derived from numerous hydrological and remotely sensed data. The flood depth is believed to be the most appropriate sign depicting the risk intensity (Islam *et al.*, 2001, 2000a-c; Townsend and Walsh, 1998; Wadge *et al.*, 1993). In identifying the flood depth it is quite imperative to categorize the natural phenomenon of a river flooding such as source flood and non source flood, which posed significant implications on the GIS model. The source flood is explained as the flood caused mainly by over flow of a river bank, which predominantly affects those areas or settlements close to the river channel, whilst the non-source flood is described as a flood caused by a well dispersed rain storm over a large area (Liu *et al.*, 1999). All the raster cells or vector points with an elevation beneath the water level are assumed to be flooded in the case of non-source flood, whilst in the case of source flood; to estimate accurately the areas affected by the flood, it is required to simulate the course of the over bank flow from the main canal to the neighboring floodplain. In estimating the depth of an inundation (Townsend and Walsh, 1998), the concept of topographical convergence or wetness index (Beven *et al.*,

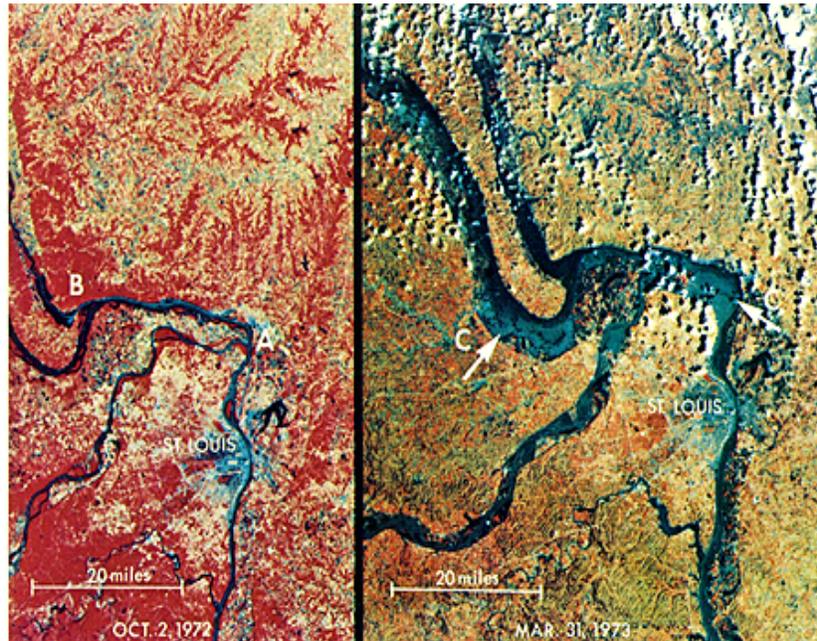


Fig. 2: LANDSAT-1 image of March 1973 mississippi river flood (source: <http://www.fas.org/irp/imint/docs/rst/Sect14/>)As a result of rapid snow melt and heavy rain, the Mississippi River in the US experienced a 100-year flood (largest expected statistically in a 100-yr) in late March of 1973. Hence, above is a LANDSAT-1 image depicting a previous pre-flood view on the left and on the right is the degree of flooding on a cloud free day

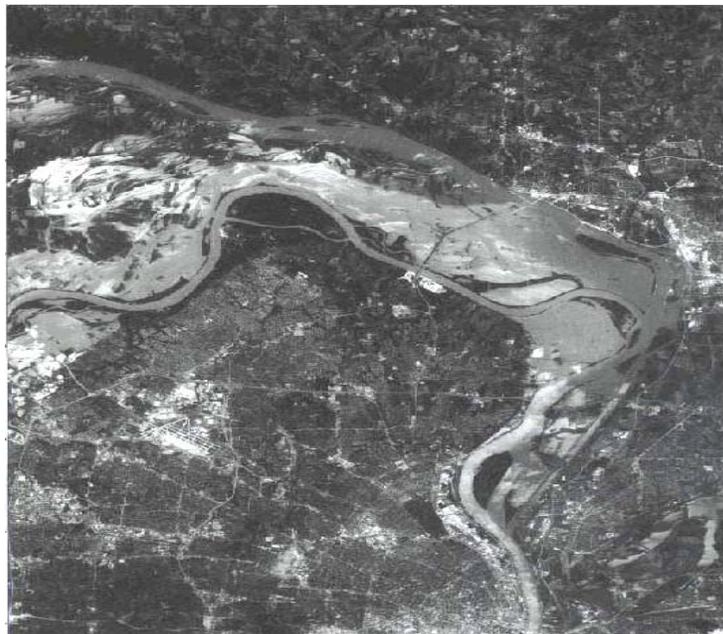


Fig. 3: SPOT PAN Image acquired on July18-10 m resolution (http://www.earthsat.com/wx/flooding/flood_93.html)Above is the SPOT PAN Image obtained by EARTHSAT on July 18, 1993 demonstrating the sharper description of features at 10 m resolution

1979; Moore *et al.*, 1991; Wolock *et al.*, 1995) was adopted. The wetness index concept is based on the hypothesis that the amassing of water in a single cell of a

raster depends on the area of the upslope region supplying water to that specific cell. The major problem of using this index is that when a slope is likely to be zero, the



Fig. 4: SPOT PAN image focused on west alton at 10 m resolution (http://www.earthsat.com/wx/flooding/flood_93.html). The image above shows the SPOT PAN Image focused on West Alton; individual houses were possibly identified as well

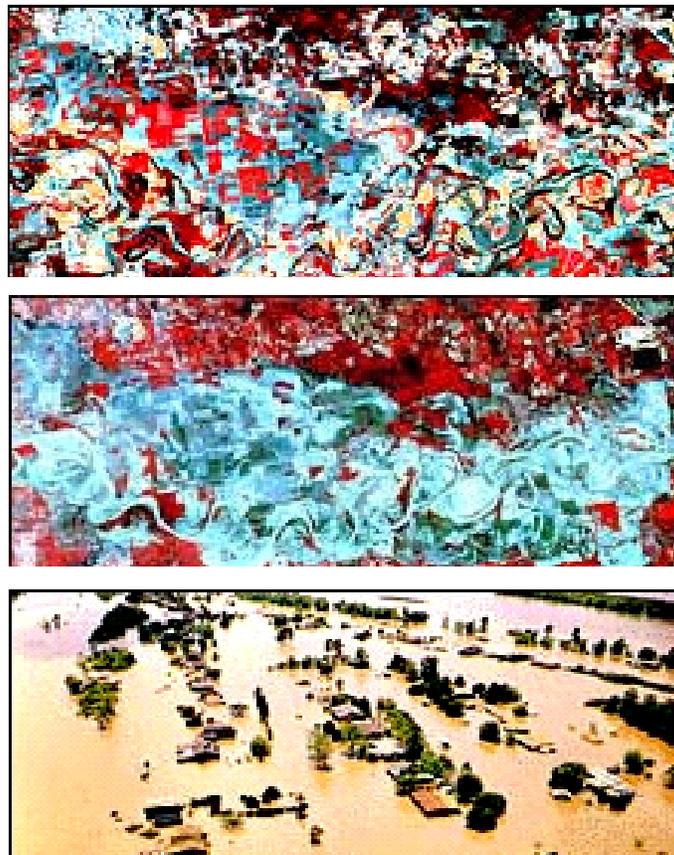


Fig. 5: SPOT image of 1990 flood of red river (<http://www.spotimage.fr/home/appli/hazard/rriver/welcome.htm>). The Figures above were taken by SPOT. The first image (upper image) illustrates the situation prior to the inundation in 1987, the second one (center image) reveals the actual condition during the inundation in 1990 and the third image (down image) reveals the areas affected by the flood during the period of the inundation

wetness index turns out to be undefined. Therefore this index is not very helpful when it comes to modeling in very plane floodplains. Another model for simulating source flooding was adopted by Townsend and Walsh (1998), which presumed that the likelihood for any area to be flooded is directly connected to the variation in elevation between that area and the river at its closest hydrological link.

Islam *et al.* (2001) possibly conducted one of the most inventive, easy and cost-effective study concerning the management flood hazard. The authors evaluated the depth of an inundation from NOAA AVHRR imageries only by the tonal variation of the inundated water. Using the supervised classification, they subdivided the flood affected area into various flood depth sectors. AVHRR data was place over a DEM so as to correctly identify the training sets. By calculating a weighted score of each and every land use, physiographic and geologic division of the country, the flood hazard was evaluated. The underline of this method is that it allocates larger weight to the classes of deeper flood depth in an exponential way. Similarly, for the low flood depth, the weight amplifies in a progressive way but ahead of a certain flood depth the augmentation of weight is greatly higher than the preceding flood depth categories. Based on this method, it ensures that regions having higher flood depth will be allocated a high hazard value. Well, the justification is that after a particular flood depth, the inundated water turns out to be very critical and detecting this serious flood depth is essential for hazard area mapping. However, the depth of serious river stage is likely to differ from one area to another area depending on the geographical setting, settlement pattern, building materials etc.

As a result of rapid snow melt and heavy rain, the Mississippi River in the US experienced a 100-year flood (largest expected statistically in a 100-yr) in late March of 1973. A LANDSAT-1 image illustrated in Fig. 2 depicts a previous pre-flood view on the left and on the right is the degree of flooding on a cloud free day. The great Mississippi flood occurred once more after a period of twenty years and damaged 11,000,000 acres of farms, communities, roads and rail links; over 50 died; dislocating millions, some permanently; costing in federal funds alone more than \$12 billion (<http://www.EARTHSAT.com/flood/sast/sast2.html>).

Remote sensing data and GIS techniques coupled with hydrologic modeling were adopted in working out solutions to alleviate potential damages and costs to the federal government. As baseline information for validating flood insurance claims, extent of the aerial view of the flooding was necessary. Therefore, SPOT PAN Image revealed in Fig. 3 obtained by EARTHSAT on July 18, 1993 demonstrates the sharper description of features at 10 meter resolution, similarly when focused on

West Alton (Fig. 4), individual houses were possibly identified.

Likewise, in 1994 during a mapping study for the flood in Albany, Georgia, a SPOT PAN image prior to flood was acquired by the Army Corps of Engineers (COE), where they tried to map the extent of damages in terms of people affected and potential cost. This was done by overlaying the district boundaries and the town limits on top of the image. Actually, the main purpose of the study was to supply to US Federal Emergency Management Agency (FEMA) a sort of parliamentary updating graphic in depicting the extent of flood as well as the nature of the collapsed sites.

After the heavy precipitation in the autumn of 1994, the Texas flood prone coastal plain got flooded. Consequently, SPOT PAN Images were used in detecting, measuring, and displaying the extent of newly geographical built-up areas, which in turn become a kind of cost effective process for assessing as well as expanding urbanization together with its connection to floodplains and flood risk. One of the advantages of this information is that it will serve as a useful tool to the risk insurance agencies as well. Hence, areas of high risk that require diagrammatic assessment can be located using the information of land use change in the form of a map.

In a related development, the 1990 Red River flood was one of the most serious inundations in Canada and south of the boarder. There are three basic images illustrated in Figure 5, which were taken by SPOT. The first image (upper image) illustrated the situation prior to the inundation in 1987, the second one (center image) revealed the actual condition during the inundation in 1990 and the third image (down image) revealed the areas affected by the flood during the period of the inundation. Therefore, how ERS SAR and LANDSAT TM can be utilized in both the evaluation and alleviation components of flood management was demonstrated by Barber *et al.* (1996). The authors reached a conclusion by discovering that high incidence angle SAR at 5.3 GHz and HH polarization are quite suitable for flood boundaries delineation. Likewise, TM data incorporated with SAR is found to be promising for well-organized calculation of the whole flooded areas, inundated areas by land use class as well as spatial relationship of these variables with other demographic, socio-economic, or cultural variables.

CONCLUSION AND RECOMMENDATION

The aforementioned discussion revealed the potentials and shortcomings concerning the application of GIS and remote sensing tools in managing the menace of flood disaster. Convincingly, remote sensing and GIS applications are the most efficient and cost-effective techniques of curtailing flood disastrous effects. All over the world, flood disaster cause injuries to human life and

property in different ways. This is actually as a result of the increased in population which has also resulted in the increased of susceptibility of humankind and their environment. Therefore, flood recurring incidences required to be examined adopting the contemporary technology in order to attain for better preventive measures. For better future situation forecasts; discovery of disaster flood prone regions; place of security measures and secure alternate ways etc can immensely be achieved with the help of the modern technologies of remote sensing and GIS. Post-disaster satellite information acquirement facilitates in disaster revitalization; damage alleges procedure and speedy reimbursement settlement. Multi date radar imageries for observing a particular flood event are been used by most of the researchers nowadays considering various image handing-out methods in overcoming the limitations of a remotely sensed information in flood demarcation. The major limitations of this kind of approach are many. So, this review paper focused on particular problem such as flood areas demarcation and most of the previous studies reviewed in this paper relied solely on the satellite data availability, to be specific a high resolution Digital Elevation Model data, which is quite difficult to obtain during the period of a peak flood especially in the monsoon period of Asia. Similarly, most of the studies discussed herein are of high cost, which in turn will be extremely difficult to be implemented by such less privilege developing countries. Hence, all these cannot become a reality without ideal high resolution DEM information. Moreover, IKONOS and SPOT 5 are very good high resolution satellite imageries but unfortunately are not often utilize when it comes to management of flood because its prices are so exorbitant to purchase. Comprehensive mapping of hydro-geomorphology revealing the hint post-floods could assist in this direction immensely (Nirupama and Simonovic, 2002). Over time, web-based GIS are becoming very much rampant. World-Wide-Web (WWW) is a very helpful means when it comes to information gathering and manipulation. Most of the information that are available in the world are now obtainable over the Internet. Nowadays, this is very much similar regarding GIS information. Previously, one need to purchase a pricey software package to make use of and maneuver the information required for GIS, alike isn't so these days. By the arrival of Java based programming, software applications for web-based GIS effort are at this time accessible. The user is required by several of these programs to purchase some software, and some need plug-ins to be included to the web browsers, however some require no additions of any special software at all. These utilize only the potentials of one's existing web browsers.

One of the advantages of the web-based GIS is that a lot of the populace who were finding it extremely difficult in accessing information they might desire or

require previously can nowadays get it at their fingertips. The public can now observe similar information regarding their environment as the policy makers for the very first time.

Lastly, a special focus should be given based on regional point of view in dealing with the flood problem. The GIS and remote sensing technologies can be very helpful for the planners to prepare a successful plan for fighting the continuous natural disaster of river flooding.

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