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Combining Microwave and Optical Sensor to Improve Post Cyclone Affected Area Mapping

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Abstract

Storm surge was adversely affected the life of people and property of coastal region of Bangladesh due to cyclone Roanu on 22 May 2016. It is important to delineate this surge extent and pattern which helps in the vulnerability assessment for relief and rehabilitation purposes. Optical sensor is not enough for outlining the affected areas. Because during cyclone, bad weather (cloud) usually prevails over the swamped area. Microwave remote sensing, can solve the problem because the radar pulse can penetrate cloud cover and it has ability to sharply distinguish between land and water. Combination of microwave and optical sensor found very useful to mark out storm surge inundated area. A change detection approach was implemented through the analysis of pre and post cyclone period. In this approach Landsat8-OLI image have been used for before cyclone and ALOS-PALSAR image have been used in after cyclonic period. Combining the PALSAR and OLI imagery using fusion method allows for the accurate depiction of such kind of violence surge extend. The study reveals that about 497698 (ha) areas have been affected due to storm surge during cyclone Roanu.

Key words: ALOS-PALSAR, Landsat8-OLI, Microwave, Optical sensor, Storm surge

Introduction

Bangladesh is one of the most disaster prone countries in the world. Every year, the country is visited by cyclones, storm surges, floods, droughts, landslides, earthquakes, etc. which affect the socio-economic condition and hamper the process of sustainable development of the country. Cyclone with storm surge is one of the most common disasters in the coastal region of Bangladesh, because Bay of Bengal is the breeding ground of cyclone. Normally it occurs in pre-monsoon (March-May) and post-monsoon (October-November) period.

A powerful cyclone Roanu struck Bangladesh on 22 May, leaving 26 dead and affecting hundreds of thousands of people. The storm brought heavy rains which caused floods and landslides across the coast of the country. It also brought a storm surge 2 m in height, which was responsible for most of the deaths when dams over flowed. Roanu and the resulting floods and landslides tore through wooden homes and buried some villages.

It is estimated that as many of 80,000 buildings were damaged and the storm also disrupted power and blocked some roads. In addition to the damage buildings suffered, the storm took a toll on agriculture, sweeping away crops and killing livestock.

Cyclones of 25 May 1985, 29 May 1991, 18 May 2004, 25 May 2009 (Aila), 12 November 1970, 25 November1988, and 15 November 2007 (SIDR) are the examples of such cyclones cause severe damages to lives and properties. In the present study, an attempt has been made to delineate the Roanu affected area over coastal region of Bangladesh using image fusion method.

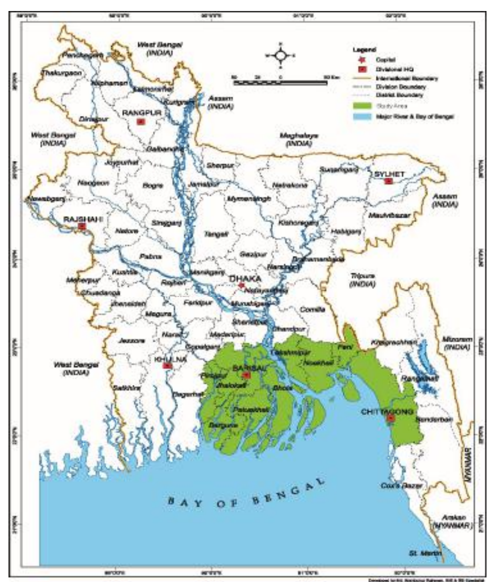

Fig. 1. Study area over administrative (District) boundary of Bangladesh

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Materials and Methods

Study area

Study area covering the coastal district of Barguna, Pirojpur, Jhalkati, Patuakhali, Barisal, Bhola, Lakhmipur, Noakhali, Feni and part of Chittagong district.

Figure 1 shows the study area over district map of Bangladesh. Major rivers of Bangladesh as well as Bay of Bengal are also shown in the map. Figure 2 shows the track of cyclone that was hit the middle of Bangladesh coast.

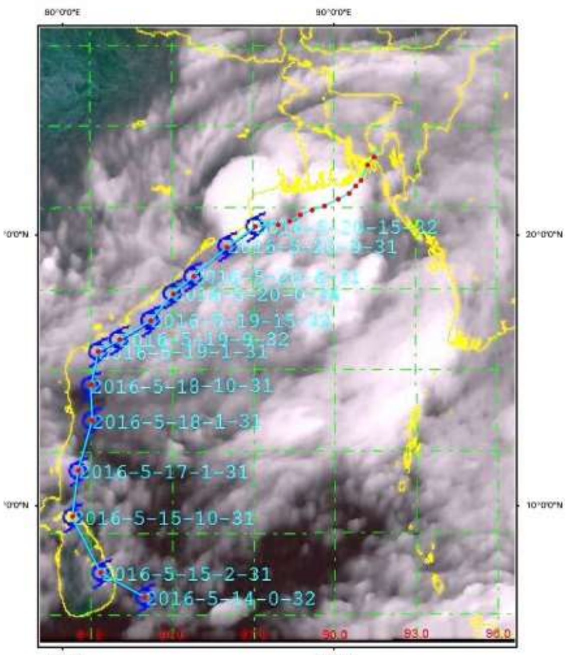

Fig. 2. Track of cyclone Roanu hit coastal district of Bangladesh on 22 May, 2016

Data generation

Mapping of inundated areas are involved data collection, pre-processing of data, thematic layer extraction, data analysis, field validation and finally produce output of study map. Figure 3 shows the flow chart of research study.

Data collection

Outlining the storm influenced area requires pre-

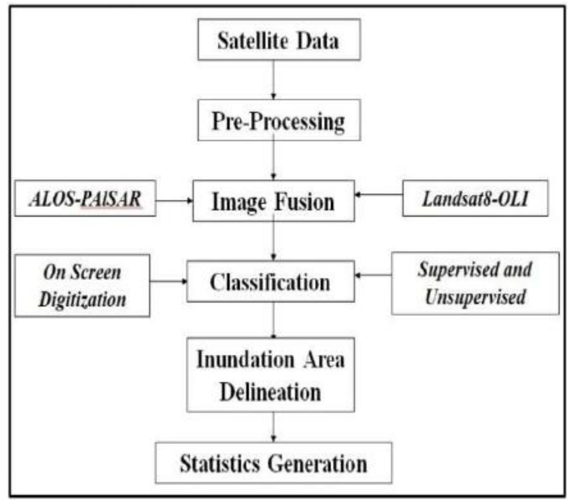

Fig. 3. Flow chart of data generation

(before) and post (after) cyclone data. ALOS-PALSAR data on 25 May 2016 (after cyclone) collected from JAXA (duel-polarization vv and hh) and Landsat8-OLI images of 16 February 2016(before cyclone) and 23 March 2016 (after cyclone) were used in this study.

Four Landsat frames required for covering the affected area. Landsat8 data have been downloaded from glovis archive of USGS (*http://glovis.usgs.gov*). All the captured data are converted to IMG format. Figure 4shows the partial image frames (136/44, 136/45, 137/44 & 137/45) of landsat8 under study area.

Application of optical remote sensing

In the initial stages of earth resource satellite remote sensing the data available was from Landsat Multi Spectral Scanner (MSS) with 80 m resolution. MSS data were used to deal with the flood affected areas in Iowa (Hallberg *et al.*, 1973), and Mississippi River basin (Deutsch *et al.*, 1973; Deutsch *et al.*, 1974; McGinnis *et al.*, 1975).

MSS band 7 (0.8–1.1µm) has been found particularly suitable for distinguishing water or moist soil from dry surface due to strong absorption of water in the near infrared range of the spectrum (Smith, 1997).

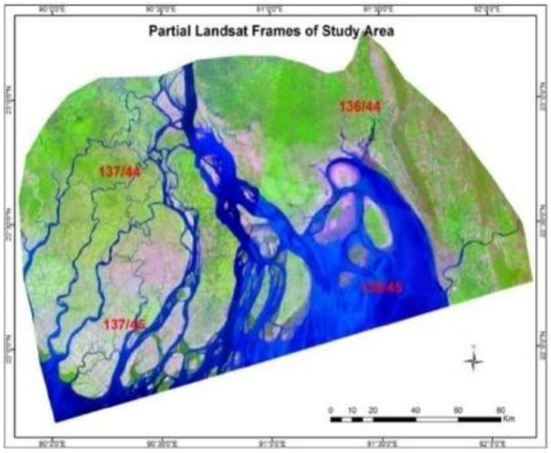

Fig. 4. Partial image frames (136/44, 136/45, 137/44 &137/45) of Landsat8-OLI under study

From the early 1985, Landsat Thematic Mapper (TM) imageries with 30 m resolution became the prime source of data for monitoring floods and delineating the boundary of inundation. Special attention was given to dealing with monsoon flooding in the developing countries like West Africa (Berg and Gregiore, 1983) and India (Bhavsar, 1983).

Land sat TM band 4 proves to be very useful in discriminating water from the dry land surface because it is a near equivalent of MSS band 7. During later stages Système Pourl' Observation de la Terre (SPOT) multi spectral imageries, were also used for flood delineation with the similar assumption that water has very low reflectance in the near infrared portion of the spectra.

But both Landsat MSS/TM and SPOT has some limitation due to temporal resolution (revisit time) 16 & 26 days respectively and has no ability to penetrate cloud cover. Apart from these medium resolution imageries (daily), coarse resolution imageries like Advanced Very High Resolution Radiometer (AVHRR) data have been also found useful for floods of a regional dimension (Wiesnet *et al.*, 1994; Huh *et al.*, 1985a–c; Ali and Quadir, 1987; Islam and Sadu, 2000a–c, 2001, 2002).

From 1999 and 2000 Terra/Aqua-MODIS (Moderate Resolution Imagine Spectrometer) found very effective to identify the flood induced area due to high-frequent observation (twice a day).Devastating floods 2004 and 2007 in Bangladesh have been studied using time-series MODIS surface reflectance data.

Application of microwave remote sensing

The existence of cloud cover appears as the single most important impediment to capture the progress of floods in bad weather condition (Rashid and Pramanik, 1993). The development of microwave remote sensing, particularly radar imageries, solve the problem because the radar pulse can penetrate cloud cover.

Currently the most common approach to flood/surge management is to use synthetic aperture radar (SAR) imagery and optical remote sensing imagery simultaneously in one project (Honda *et al.*, 1997; Liu *et al.*, 1999; Chen *et al*., 1999). Apart from its all-weather capability the most important advantage of using SAR imagery lies in its ability to sharply distinguish between land and water. Change detection can be used as a powerful tool to detect flooded area in SAR imagery. It is generally performed by acquiring two imageries taken before and after the flood. Coherence and amplitude change detection techniques are widely applied in SAR domain. In the amplitude approach, areas are estimated as flooded where the radar back scatter is observed to be in considerable decline from before flood to after flood imagery. In the coherence approach areas are generally identified as flooded where the coherence or correlation of radar backscatters from before and after flood imagery are very low (Nico *et al.*, 2000).

Multi-date SAR scenes for the same area can be projected to red, green and blue channels to create a color composite. Long *et al*. (2001) used three ERS SAR scenes to produce this kind of composite image. The composite image effectively depicts progress of a flood during a specific time period.

This methodology is simple to execute and provides an opportunity to readily identify the area that remains water logged for a maximum period of time. The existing studies pointed out some common problems encountered in accurately extracting the storm surge affected area from SAR imageries. A major problem is associated with the relation between radar wave length and roughness of the terrain and water body.

Normally pure and calm water acts as a specular reflector to the radar signals. Thus the radar antennae receive no backscatter and the water appears in dark tone in the SAR imageries. Rough water surface appears in brighter tone in the SAR imageries than the calm water (Yang *et al.*, 1999).

During or after cyclone, bad and windy condition usually prevails over the devastated area. Wind induced ripples in the water surface frequently creates problems for the interpreter to determine the threshold value to demarcate the submerged area.

Data pre-processing

Data Pre-processing are involved atmospheric correction, geo-referencing & resampling, sub-setting, etc. Atmospheric correction of Landsat8-OLI has been done using dark screening method (Sarker and Rahman, 2007). Geo-referencing was done by existing geo-referenced image collected from SPARRSO archive. In geo-referencing/re-sampling method Bangladesh Transverse Mercator (BTM) projection system was used.

Image fusion approach

Table1. Statistics of storm surge affected areas

Classification	Unsupervised (ha)	Supervised (ha)	Field Information (ha)	Remarks
Common Water	769535	768227	Not required	Supervised classification found best result
Storm Surge Affected Areas	**496576**	**497698**	**497450**	
Common Land	1532150	1532336	Not required	
Total Area	**2798261**	**2798261**		

SPARRSO has a facility to receive real time data from FY-2D for monitoring cyclone as an hourly basis. It has also Terra/Aqua-MODIS ground station for receiving real time data twice a day and available facilities for downloading of Landsat8-OLI data before and after cyclone.

Both MODIS and OLI data are not so enough for defining such kind of inundated areas due to optical sensor (already described).The ALOS-PALSAR data collected after cyclone period (25 May 2016) is not so enough to outline storm surge damaged area due to duel polarizations vv & hh. Synthesizing the PALSAR and OLI imagery using fusions methods at ERDAS imagine environment allows for the accurate depiction of storm surge/flood extend. Principal component method and cubic convolution resampling technique have been applied for merging ALOS-PALSAR and Landsat8-OLI images.

Data generation

The fusion image have been used which helps identification of storm influenced areas, common (river) water and land. The RGB false color composite has been prepared for visualizing the land features. Then the multi-spectral classification using unsupervised (ISODATA) and supervised classification (parallelepiped and maximum likelihood techniques) were done and results have been compared. Based on the field investigation and secondary data, it is found from the Table-1 that the supervised classification using maximum likelihood provides best results for setting down the submerged areas.

Field survey data

During field survey information aimed at accuracy assessment was collected. This was collected at field-to-field basis and is also known as wall-to-wall ground truth. A cadastral map of the study area have been used for the collection of field-wise information on water extend. The areas from where data has been collected, need to be located accurately on satellite images hence, their spatial extent and geographical coordinates need to be recorded during data collection using GPS (Global Positioning System). The collected data was incorporated using GIS and on screen digitization techniques. Table 1 show the field information collected from field after cyclone Roanu.

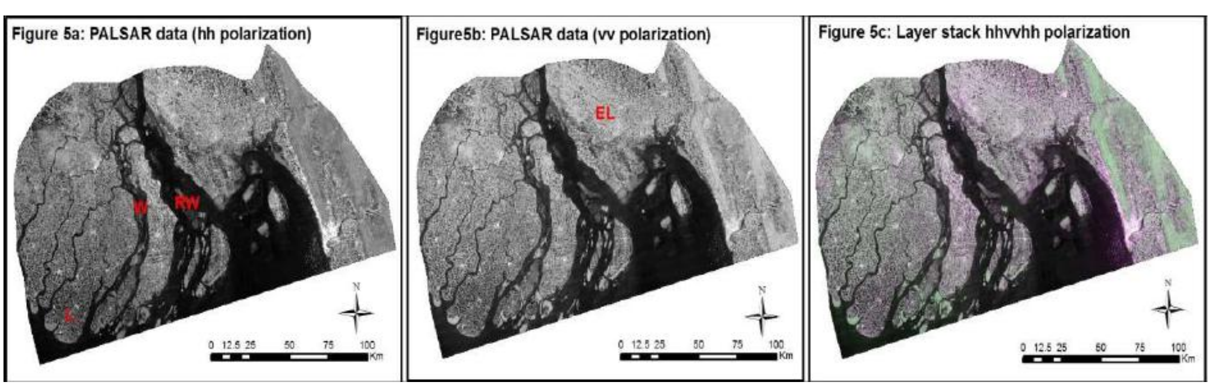

Fig. 5. Different polarization of ALOS-PALSAR data of the study area

Results and Discussions

Storm surge affected area mapping have been analyzed based on the visual interpretation of PALSAR/OLI images and multispectral digital classification /threshold as well as on screen digitization techniques of fusion image to depict the accurate result. The results of the analysis are discussed below.

Visual interpretation of PALSAR data

Due to duel polarization and only post cyclonic condition of PALSAR data is not so enough for outlining the affected area by storm because the image color, tone, texture, spectral reflectance of river water and that of close water (surge/flood induced area) are similar figure 5 (left) and 5 (middle). As an example in figure 5 (left), 5 (middle) & 5 (right) it is clearly seen that point 'L'(figure 5 left) stands belongs to storm concerned area and point 'W' belongs to river but both points represent black color.

Location of 'RW' in figure 5 (left) belongs to river water but it shows whiter like as open land. Same color and tone appear in figure 5 (middle) & 5 (right) in same

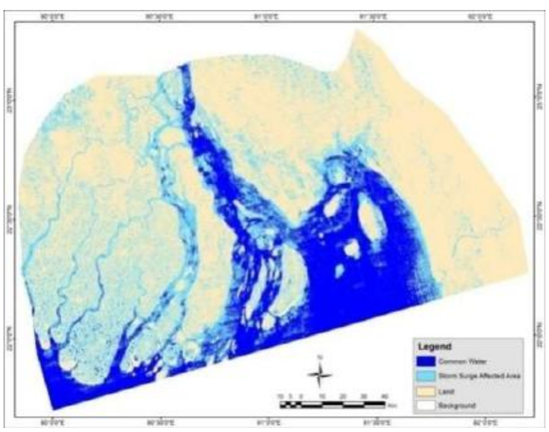

Fig. 6. Classified image of PALSAR data (25.5.2016)

places. In figure 5(right) some areas are shows greenish color. Those are belongs to hilly and mangrove plantation areas. The spectral reflectance value (DN) of points 'W' in figure 5 (left) is almost closer to 34 in other two images. In point RW (figure 5, left), the DN value closer to exposed land 'EL' (figure 5, middle) value around 140 in all images of figure 5.

Limitation of PALSAR data

Attempt has been made to separate immersed area from land and common (permanent) water using threshold technique. Layer stack (hh+vv+hh) of PALSAR image of figure 5 (right) has been used for classification.

It is clearly seen from the classified PALSAR image (figure 6) that most of the river appears storm surge stirred area due to generated water wave by wind. It is noted that during and after cyclone bad weather prevails of the spoiled areas and surrounds.

So it is difficult to separate storm surge/flood water from land. It is one of the major problems of SAR data. This problem has been overcome by merging SAR image and optical image (OLI).

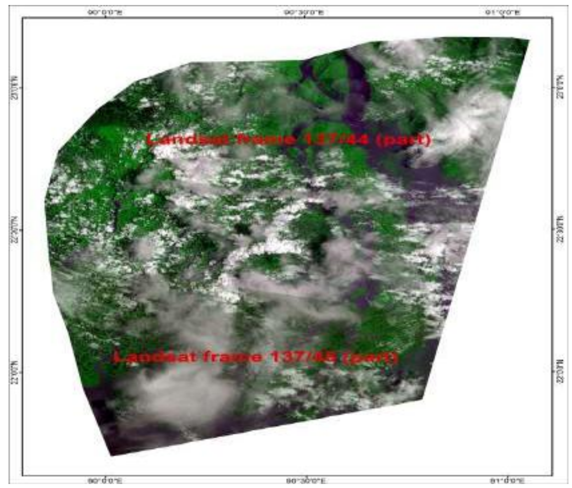

Fig. 7. Image of Landsat8-OLI on 23 May 2016

Limitation of optical data

Generally during and after cyclone bad weather prevails of the concerned areas and surrounds. So it is difficult to define the distressed area by optical image because optical data has no ability to penetrate the cloud cover.

Figure 7 shows the partial Landsat8 frames of 137/44 and 137/45 (23 May 2016, after cyclone). Data of Landsat8 frames 136/44 and 136/45 during after cyclonic period was not available.

In figure 7 it is clearly seen that white color shows cloud, green color vegetation and blue color water. Most of the area of the image is covered by cloud. Due to cloud it is difficult to separate storm surge affected area from common water and land. This problem has been overcome by joining SAR image and optical image (OLI).

Analysis of image fusion method

Merging the PALSAR and OLI imagery is more depiction for cyclone affected areas like Roanu. The advantage of image fusion helps in the distinction of different regions of the image compared to the single and dual polarization PALSAR images after cyclone. The identification of objects in a scene found enriched and more accurate.

Figure 8 shows fusion image FCC (5^R, 4^G, 3^B) of study area. In fusion image we have used cloud free landsat8 image of 16 February, 2016 (figure 4, before cyclone) and PALSAR image of 25 May 2016 (after cyclone, figure 5).

Visual interpretation of fusion image shows clear distinct between storms surge affected area and common (river) water as well as vegetation and exposed land. In figure magenta color and river water appears dark blue 8, the damaged area striking by cyclone shows color. White color shows urban and exposed land, ash color shows hill and mangrove plantation areas.

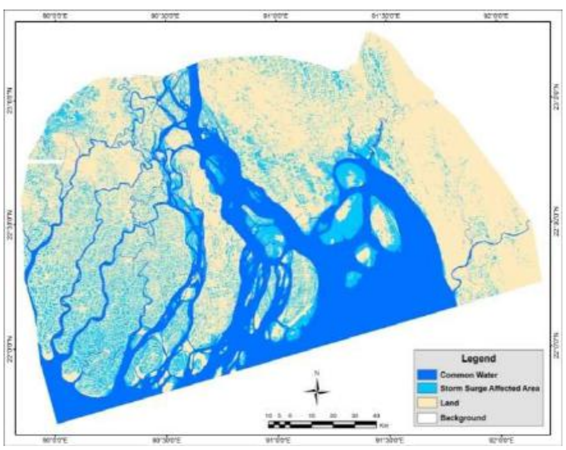

Fig. 8. Fusion image of ALOS-PALSAR and Landsat8-OLI

Figure 9 shows the classified image derived from fusion image (figure 8). It is clearly seen from the figure 9 that Roanu inundated areas are clearly distinguish from river (common) water and land. From table 1 it is clearly seen that distorted area 497698 (ha) of supervised classification and field information collected from field (after cyclone) found almost same 497450 ha compare to unsupervised classification about 496576 ha.

Areas of common water for supervised and unsupervised classification found 768227 ha &769535 ha and land 1532336 ha &1532150 ha, respectively.

Field information of common water and land were not considered during the field visit because our major/only objective of this study was to define the storm surge induced area delineation.

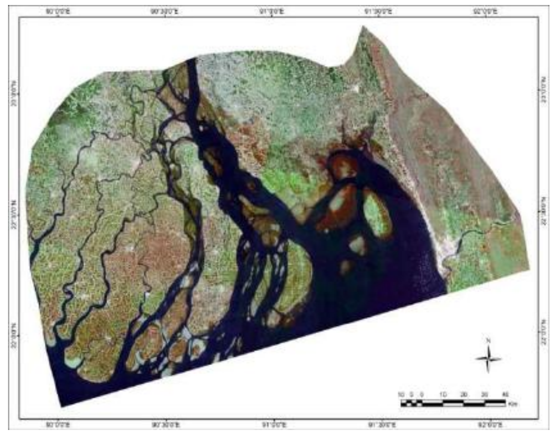

Fig. 9. Classified image derived from fusion image of study area

Conclusions and Recommendation

Cyclone Roanu hit Bangladesh coast on 22 May 2016. The storm brought surge with heavy rains which caused floods and landslides across the central coast of the country. An attempt has been made to demarcate the cyclone (Roanu) smashed area using microwave and optical satellite data. But both the data has some advantages and disadvantages.

Generally during disaster like cyclone most of the time the bad weather (mainly wind and cloud) prevails over the damaged area. Optical data has no ability to penetrate the cloud. SAR data is very much useful for such purpose because it can penetrate the cloud cover. But a major problem is associated with the relation between radar wave length and roughness of the terrain and water body. Wind induced ripples in the water surface frequently creates problems for the interpreter to determine the threshold value to delineate the storm surge affected area.

Combination of microwave and optical sensor found very useful to set down the destroyed areas. A change detection approach was implemented through the analysis of pre (before) and post (after) cyclone period. In this approach Landsat8-OLI image have been used in post cyclone period.

Aggregating the PALSAR and OLI imagery using fusion method allows for the accurate depiction of storm surge extend. The study reveals that about 497698 (ha) areas have been affected due to storm surge during cyclone Roanu.

This will be helpful for decision makers for relief and rehabilitation purposes to real victims. Due to some individual disadvantages both microwave and optical data, fusion method is very much useful for flood/storm surge affected area delineation.

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