USE OF MULTI-TEMPORAL RADARSAT-1 SCANSAR DATA TO DIFFERENTIATE BETWEEN FLOODED AND NON-FLOODED AREAS

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1. Introduction

The advantages of using satellite data in flood mapping are the availability of the data at near real-time, relatively low cost for mapping a flood of large areas and the effectiveness and robustness of the flood mapping methods (Wang et al. 2002). Precise flood extent mapping is also required to identify deficiencies of existing flood control measures (Smith, 1997). Active remote sensing such as ERS-1/2, Radarsat-1 uses Synthetic Aperture Radar (SAR) sensor on board that is capable to image the earth regardless of cloud and light compare to traditional passive sensor (Landsat TM, for example). Therefore, SAR data becomes an inevitable data source to the hydrologic community for flood event analysis. The Canadian Radarsat-1 satellite has been in operation in 1995. Since then Radarsat-1 SAR data have been used for assessing flooding in many parts of the world with variable accuracies (Townsend, 2000; Adam et al. 1998; Toyra et al. 2002).

Dhaka City, the capital of Bangladesh is subject to flooding annually during the monsoon season. However, the extent and magnitude of flooding varies depending on rainfall and discharge from the upstream. The 1998 flood is described as one of Bangladesh's worst flood this century that submerged more than 70 percent of total land with varying magnitudes (Faisal et al. 1999). Dhaka City, the capital and home to more than 10 million people, was also badly affected in 1998 flood that inflicted its major parts. Although, flood is an annual event in the city, however, remote sensing studies of flood never considered for the accurate delineation of flood prone areas. This paper is an attempt to employ Radarsat-1 ScanSAR data to differentiate between flooded and non-flooded areas during the 1998 flood event which can provide the widest and maximum flood extent in the city.

2. Data and Methodology

In order to precisely delineate flooded and non-flooded areas, multi-temporal approach has been used that comprises of using Radarsat-1 SAR data from early to peak flooding of the 1998 event. There were four steps involved to discriminate flooding and non-flooding area. They are:

(1) Suppression of speckle of Radarsat-1 data using GAMA-MAP filter with 5x5 window size.

(2) After speckle suppression, all data is geocoded in one projection system. Image-to-image registration technique is used to geocoded images. The geocoding was done using a Landsat-TM geometrically corrected image as the reference image. A second order polynomial fit was applied and pixel values were resampled into 50m.

(3) In order to extract flooding and non-flooding boundaries from SAR data, image segmentation approach was utilized by thresholding each image. Threshold value for each image was obtained from image histogram upon subtracting all flood time images from the 15 December (dry season) image in order to get the changed areas and threshold value.

(4) Classification accuracy of remotely sensed data is performed by comparing individual classified image with ground truth map. Overall accuracy and Kappa value have been computed to understand the accuracy of remotely sensed classification.

3. Result

(a) Calculation of Inundated areas

Prior to the calculation of inundated area percentage, image classification was performed into flooded and non-flooded areas. A threshold value for classification categories were obtained from image histogram for each image. Then a model considered in a remote sensing platform to classify images into two distinct classes. Estimation of inundated areas was performed using the following formula, inundation area percentage = a/(a+b) x 100.............(1), where a = inundated area, b= land area during the flood. It is necessary to mention here that all flood time images was compared with a dry season image of 1998 flood with a view to depict precise inundation areas. The analysis shows that inundated area (**Table 1**) was steadily increased from July 07, 1998 (34.30%) and reached its peak in 25 August (53.93%).

Table 1 Estimated Inundation Area Percentage during 1998 flood

Image dates	Inundation Area Percentage (%)
07 July 1998	34.30
31 July 1998	36.70
10 Aug. 1998	45.35
25 Aug. 1998	53.93
10 Sept. 1998	43.54
17 Sept. 1998	43.06
11 Oct. 1998	29.29

Three hypotheses can be made concerning the presence of water, either it rained again or more waters came down from the upstream and spread over already flooded zones hence increasing the affected area or both phenomena occurred simultaneously. In order to ascertain our hypotheses, rainfall and water level data were incorporated and analyzed. Rainfall records confirmed one of the hypotheses which revealed that remarkable changes of rainfall in the month of August, which was 367.8 mm higher than the normal, caused more areas to be flooded. In addition, the back water effect from downstream rivers causes flood water to recede at a faster rate (IFCDR, 1998). Although flood movement can be displayed with the composite image, however with a view to present the dynamic and accurate map of inundated areas during the 1998 flood in the study area, it was necessary to convert raster flood images into vector format and show all layers as a composite flood map (**Fig. 1**). The composite map (Fig. 1) revealed that most of the western part of the city did not suffer from flood. This was due to relatively higher elevation of this portion than other parts of the city. In addition, this area was brought under flood protection by constructing 31.67 km long embankment right after the 1988 massive flood under Flood Action Plan (Faisal et al. 1999). However, the embankment itself created obstacle to receding flood water. Most importantly, infiltrated water in the embankment created severe internal drainage problem and heavy rainfall caused more areas to be flooded (IFCDR, 1998). Interestingly, in the eastern part of the city, inundation is largely dominated by the river water while in western part incessant rainfall together with river waters are the main determinants.

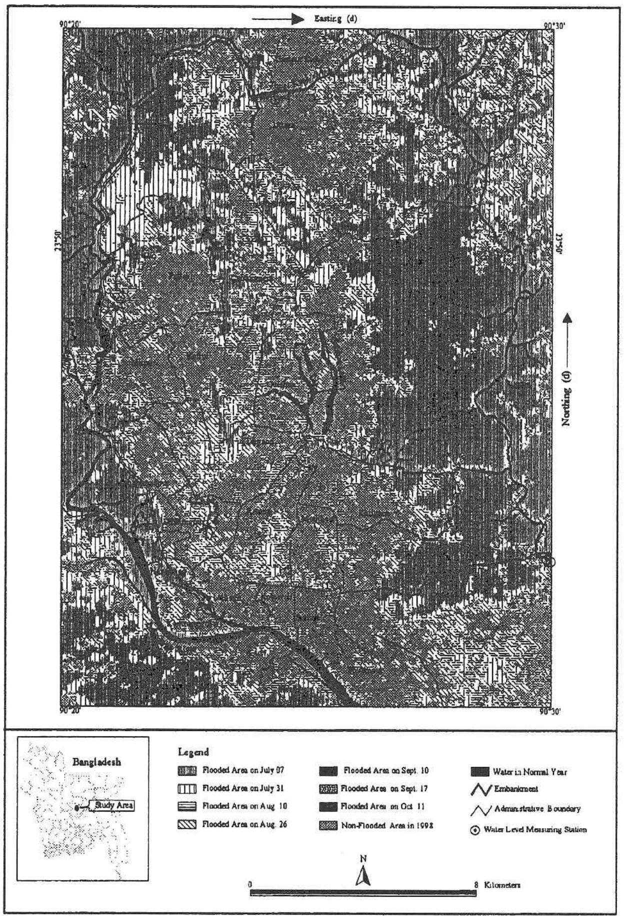

Fig. 1 Composite flood map of the study area during 1998 flood

(b) Accuracy Assessment

After classifying remotely sensed data, the accuracy of the results need to be assessed with field data. This is commonly referred to as accuracy assessment (Campbell, 1987). Accuracy of classified images was performed in the following manner. First, a total of 300 random pixels (at least 100 for each class) were generated for each classified image. Then the ground truth map was overlaid on it and sample pixels were verified one by one. The computation of overall accuracy of individual image date (**Table 2**) shows that good accuracy is attained for July-September images while the overall accuracy for 17 Sept. and 11 Oct. was comparatively poor . This was mainly attributed to the errors present in SAR data (Henderson and Xia, 1998). Possible errors are lower radar returns from open spaces, features adjacent to water bodies, presence of radar shadows etc. In order to subjugate errors associated with SAR data different techniques were applied (Henderson and Xia, 1998), and thus the result improved. The Kappa coefficient for each of the classified image listed in **Table 2**. It revealed that the July 7 1998 data has obtained good agreement (75.67%) while 17 September data has produced the least agreement with corresponding ground map.

Table 2 Classification accuracy of Radarsat-1 Images

Image dates	Overall accuracy (%)	Kappa Coefficient (%)
07 July 1998	85.33	75.67
31 July 1998	85.00	69.53
10 Aug. 1998	77.33	48.76
25 Aug. 1998	78.33	53.04
10 Sept. 1998	79.00	57.85
17 Sept. 1998	55.85	17.88
11 Oct. 1998	64.33	21.81

4. Conclusion

Radarsat-1 data is very useful for inundation mapping. In this study, multitemporal Radarsat-1 ScanSAR mode data have been used to delineate flood prone areas in Dhaka City, Bangladesh during the 1998 catastrophic event. The result of the study demonstrated that flood water started to rise from early July and reached its apex on 25th August of 1998 following heavy monsoonal downpour. Good accuracy is obtained for the data set except 17 Sept. and 11 Oct. image. It can be said that RADARSAT-1 SAR application for urban flood monitoring is very pressing to a fast growing cities like Dhaka and elsewhere that can reduce flood losses and damage in mega cities in the world.

References

Adam, S., Wiebe, J., Collins, M., Pietroniro, A., (1998): RADARSAT Flood Mapping in the Peace-Athabasca Delta, Canada, Canadian Journal of Remote Sensing, 24 (1), 69-79.

Cambell, J.B., (1987): Introduction to remote sensing, The Guilford Press, London, p. 334.

Faisal, I.M., Kabir, M.R. and Nishat, A., (1999): Non-structural flood mitigation measures for Dhaka City, Urban Water, 1, 145-153.

Henderson, F.M. and Xia, Z., (1998): Radar Applications in Urban Analysis, Settlement Detection and Population Estimation, IN: Henderson, F.M. and Lewis A.J. (edited), Principles and Applications of Imaging Radar, Manual of Remote Sensing, Vol.2, John Wiley and Sons, USA, pp. 733-763.

Institute of Flood Control and Drainage Research (IFCDR), (1998): Impact of 1998 Flood on Dhaka City and Performance of Flood Control Works, Dhaka, pp. 76.

Smith, L.C., (1997): Satellite Remote Sensing of River Inundated Area, Stage and Discharge: A Review, Hydrological Processes, 11, 1427-1439.

Townsend, P. A., (2001): Mapping Seasonal Flooding in Forested Wetlands using Multi-Temporal RADARSAT SAR, Photogrammetric Engineering & Remote Sensing, 67(7), 857-864.

Töyra, J., Pietroniro, A. and Martz, L.W., (2002): A Multi-sensor approach to wetland flood monitoring, Hydrological Processes, 16, 1569-1581.

Wang, Y., Colby, J.D. and Mulcahy, K.A., (2002): An efficient method for mapping flood extent in a coastal floodplain using Landsat TM and DEM data, International Journal of Remote Sensing, 23(18), 1681-3696.