MAPPING EXTENT OF FLOODED AREASUSING SENTINEL-1 SATELLITE IMAGE

Tran Kim Chau[1]

Abstract: *This paper presents a methodology to determine inundation area in a flood event in Ha Tinh Province, Vietnam, by applying Synthetic Aperture Radar (SAR) image processing, in combination with Digital Elevation Model (DEM) for threshold detection. Sentinel-1 images were down loaded from an open source provided by European Space Agency (ESA). DEM data were collected from United States Geological Survey (USGS). The method uses thresholds to distinguish flooded area from unflooded area. Then based on topographic correlations to identify more appropriate floodplains. The study suggesteda quickerway not only to detect flooded areas, but also to validate the use of hydraulic models in the regions where no observation data were collected.*

Keywords: Synthetic Aperture Radar; Sentinel-1; water boundary detection; inundation mapping.

1. INTRODUCTION

Floods are among the most devastating and widely distributed natural hazards in Vietnam and the world. Every year, floods cause more economic and social damage than any other types of natural disaster.Loss fromflood related hazards cost Vietnam about1billion USD annually (UNISRD, 2015). Therefore, natural disaster management and risk reduction havealways been an important governance target of Vietnam Government. In recent years, inundation mapping hasbecome a powerful tool for disaster management and mitigation. Previously, detection of floodedareas in Vietnam hasmostlybeen computed on hydraulic models (e.g Pham el at 2014, Dang el at 2015). While this approach can be effective, model constructionhas been time-consuming and expensive, especially when surveying cross-sectional data. As a result, water resource researchers in Vietnam have searched for more innovative methods that are faster and cheaper to simulate better real time flooding.

The growing availability of digital imageries captured by aircraftsor satellites has led to an expansion of remote sensing technique for surface water detection. This depends on the characteristics of sensors (number of bands, ground resolution, etc.), and the scale of the investigation (long/short-term, large/small-scale, etc.). Due to anincredible number of applications of remotely sensed data, water detection techniqueshave improvedsignificantly. The combination of bands to create false colour was an initial method to distinguish water and land.Using this technique, inundation mapshave been well delineated fromsatellite imageries, such as Landsat, ASTER, SPOT, etc.

Among two types of satellite images, optical satellite images are only useful in clear weather conditions. During storms, it is not possible to define the ground objects clearly asthe sky iscovered by clouds. Meanwhile, active satellite images are suitable to detect open water areas in storm and rainy events. However, application of SAR data was rather limited in the pastdue to thehigh initial cost of data purchase, and the complexity of image interpretationfornon-expert users.Recently, theEuropean Space Agency (ESA) has launched Sentinel-1sensor and opened access to the public. Withhigh resolution (10 meters) andfree cost, SAR images are becominganefficientresourceforscientists in natural

[1] *Hydrology and Water Resources Faculty, Thuy Loi University.*

resource management.Around the world, active remote sensing imageshavebeen studied by many authors. Donato Amitrano (2014) used the Sentinel 1 image to monitor areservoir. NataliiaKussul (2011) used an artificial intelligence network to assess floods for many of the world's major floods. Despite its wide usethroughout the world, very littleresearch has paid attention to use this open imagery resourcein Vietnam.

Ha Tinh is a province on the North Central Coast of Vietnam. It is located from 17°54'N to 18°37'N and from 106°30'S to 105°07'S. The province is narrow, sloping and tilted from west to east with an average slope of 1.2%. This area is hit frequently by storms and floods eachyear. In this paper, we will present an analysis of water surface detection for the October 2016 flood event in Ha Tinh Province. To study impacts of the flood, the Sentinel-1 satellite image on October 24, 2016 was downloaded for analysis. Based on that image, an inundation map of Ha Tinh area was made.

2. METHEODOLOGY

The active sensor transmits a microwave (radio) signal towards a target and detects backscattered radiation. Different objects reflect different amount of energy, depending on the characteristics of ground material (structural, chemical, and physical), surface roughness, an angle of incidence, and intensity. When comparing to land surfaces, incoming signal to flat surface water body reflects away from the sensor, so that the sensor receives a low backscattered signal, making the appearance of water dark in SAR images. Though many image processing indexes have been developed to detect reflection signals, in this study, the Normalized Difference Water Index (NDWI) combining GREEN and Near-Infra Red (NIR) wave lengths is used to detect water body (Mc Feeters (1996, 2013).

A complete water detection algorithm is a cascaded approach which is composed of several steps. The first step is preliminary data processing, which includes radiometric correction, filtering, and calibration. Although water detection could be carried out without thresholds of elements, water-land classification is often needed to reduce the uncertainty. This study combines the Sentinel-1 image with AsterGDEM data (to increase the accuracy of flood extent estimation. Flowchart of the analysis is described in Figure 1below.

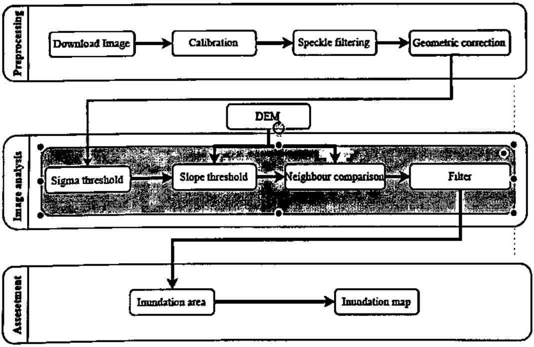


Figure 1. The flowchart of study procedure

In the preprocessing process, the Sentinel-1 image is downloaded from Sentinels Scientific Data Hub. In the calibration process, pixel value is converted to radar backscatter. SAR images have noise called speckles which degrade the quality of the image and make the interpretation of features more difficult. Speckles are caused by random constructive and destructive interference of the de-phased, but coherent return waves scattered by the elementary scatters within each resolution cell. Speckle noise reduction can be applied by Speckle filtering processing. Due to topographical variations of the scene and the tilt of satellite sensors, the distance would be distorted in SAR images. Terrain corrections are runto compensate for these distortions so that the geometric representation of the image is as close as possible to the real ground. This process is done on SNAP 5.0 application.

In image analysis, the first step is todetermine sigma thresholds. In this step, backscatter threshold is used to classify water body and land. Since water cannot stand on sloped areas, slope threshold is used to reduce an effect of hill shadow. Threshold valuesare defined through trial and error to find the best matching result.

The experiment results showed that the backscatter thresholdand slope threshold were foundat 0.05 and 10% as the most reasonable result. To increase the quality of the results, water cells were compared with neighbor cells based on elevation value extracted from DEM data (Figure 2). On the other hand, if all lower cells were land cells, the questioned cell were treated as a land cell (Figure 2a). On the other hand, if one of the lower cells was water, it was treated as a water cell (Figure 2b). An additional step is added to remove noise by major filter processing.

Based on results of water surface detection from previous steps, in the final step, flooded areas are delineated by geographic information system technology. An inundation map is then created in ArcGIS. This result illuminates a new quantitative approach on flood extent assessment.

Water	Land	Land
Water	Water	Land
Water	Land	Land

+

Higher	Lower	Lower
Higher		Lower
Higher	Higher	Lower

	Land	

a)

Water	Land	Land
Water	Water	Land
Water	Water	***Water***

+

Higher	Lower	Lower
Higher		Lower
Higher	Higher	***Lower***

=

	Water	

b)

Figure 2. Compare with neighbor cells to determine water cells or land cells

3. RESULTS AND DISCUSSION

Figure3 below shows the inundation map of Ha Tinh Province for the flood event on October 24, 2016. We computed and compared the area of water body before and during the flood. In some large reservoirs such as Song Rac (figure 4a), Ke Go (figure 4b) surface water areas increased by 210 ha and 416 ha, respectively. Total inundation area of Ha Tinh Province was 258.62 km^2. Detail data is presented in Table 1.

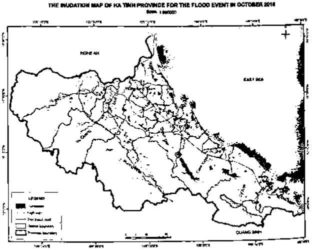
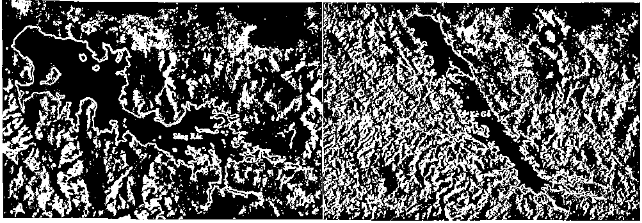


Figure 3. The inundation map of Ha Tinh province for the flood event in October 24, 2016



(a) (b)

Figure 4. Water surface areas of Song Rac and Ke Go before (yellow line) and during (red line) flood event

Table1. Inundation area in Ha Tinh province

ID	District	Inundation Area (km^2)
1	Cam Xuyen	55.43
2	Can Loc	18.22
3	Duc Tho	19.23
4	Ha Tinh City	7.24
5	Hong Linh Town	2.33
6	Huong Khe	26.33
7	Huong Son	24.75
8	Ky Anh	26.44
9	Ky Anh Town	33.95
10	Loc Ha	13.21
11	Nghi Xuan	16.39
12	Thach Ha	25.01
13	Vu Quang	15.24

Since this method only applies to "open air" areas, inundation map derived from satellite imagery will not be ascontinuous as a flood map computed by a hydraulic model, especially among residential areas, or areas covered by trees. The presence of objects above the water surface will affect the continuity of the floodplain. Besides, restriction to use this approach cannot detect level of water depth at the sites.

The advantage of this method is the ability to map flood extent areas in dependent of weather, day light, having large coverage. In comparison with the traditional hydraulic model, a satellite image can detect flooded areas where that are inside protected areas by dike systems. This study proposes a new approach to overcome the inadequacies of hydraulic models in order to provide a useful tool for decision makers.

With a 10-meter resolution, the Sentinel-1 satellite image processing result showed a highly accurate map for flood assessment purpose. Inundation areas were detected not only in major rivers but also in small rivers and canals. In addition, change of reservoir's boundaries when water level rise in flood eventwasclearly defined.

4. CONCLUSION

This paper determined the extent of the severity of flood affected areas in Ha Tinh Province with the use of SAR satellites supplied by the European Space Agency. The difference thresholds were applied corresponding with DEM was the foundation of this research. This methodology has provided a new approach to disaster management and risk control. Moreover, this method proves to have many advantages including free input data, quick calculation, and highly accurate results. This approach represents an extraordinary opportunity for future projects in low-income countries, including Vietnam.

REFERENCES

Dang Dinh Doan, Ngo Anh Quan, Nguyen Hoang Son, Nguyen Ngoc The (2015) "*Nghien cuu xay dung ban do ngap lut vung ha luu song DakBla*", Journal of Water Resources Science and Technology, **28**, 34-42.

Donato Amitrano, Gerardo Di Martino, Antonio Iodice, Francesco Mitidieri , Maria Nicolina Papa, Daniele Riccio and Giuseppe Ruello (2014) "*Sentinel-1 for Monitoring Reservoirs: A Performance Analysis*", Remote Sensing (ISSN 2072-4292).

Pham Thi Huong Lan, Ngo Le Long, Nguyen Hoang Son, Tran Kim Chau (2014) "*Construct an inundation map and propose flood prevention solutions for Lam river basin*", Proceeding of Annual Conference on Water, Water Resource University.

Stuart K. McFeeters (1996). "*The use of Normalized Difference Water Index (NDWI) in the delineation of open water features*", International Journal of Remote Sensing, 17(7):1425–1432

Stuart K. McFeeters (2013) "*Using the Normalized Difference Water Index (NDWI) within a Geographic Information System to Detect Swimming Pools for Mosquito Abatement: A Practical Approach*", Remote Sensing (ISSN 2072-4292).

UNISRD (2015). "*Global Assessment Report on Disaster Risk Reduction*", United Nations, Geneva, Switzerland. Retrieved from: http://www.preventionweb.net/english/hyogo/gar/2015/en/home/GAR_2015/GAR_2015_1.html

Kussul N., Shelestov A., Skakun S. "*Flood Monitoring on the Basis of SAR Data*", NATO Science for Peace and Security Series C: Environmental Security, 2011, pp. 19-29. (http://dx.doi.org/10.1007/978-90-481-9618-0_3)

Abstract:

XÂY DỰNG BẢN ĐỒ NGẬP LỤT DỰA TRÊN ẢNH VIỄN THÁM CHỦ ĐỘNG SENTINEL-1

Trong bài báo này chúng tôi sẽ trình bày các kết quả nghiên cứu xác định vùng ngập lụt bằng ảnh rada khẩu độ tổng hợp (SAR). Nghiên cứu được sử dụng ảnh Sentinel-1 của cơ quan vũ trụ Châu Âu cung cấp, kết hợp với mô hình số hóa độ cao (DEM) để xây dựng bản đồ ngập lụt cho khu vực tỉnh Hà Tĩnh. DEM địa hình được thu thập từ cục Khảo Sát Địa Chất (USGS). Phương pháp sử dụng các ngưỡng để phân biệt vùng ngập nước và vùng không bị ngập. Sau đó dựa vào cao độ của các điểm được cho là ngập nước với khu vực xung quanh để xác định những vùng bị ngập một cách hợp lý hơn. Kết quả của nghiên cứu không chỉ đưa ra phương pháp đánh giá mức độ ngập lụt nhanh chóng, không phụ thuộc vào các điều kiện thời tiết mà còn cung cấp cơ sở để kiểm định các kết quả của mô hình thủy lực đối với những vùng không có số liệu thực đo.

Từ khóa: *Ảnh viễn thám chủ động; Sentinel-1; phân biệt nước; bản đồ ngập lụt.*

Ngày nhận bài: 06/7/2017

Ngày chấp nhận đăng: 06/9/2017