Flood Observation Map in Banten Province Using Radar Images, Case Study: Cidanau, Ciujung, Cidurian River Basin

Propezite Nurhutama Mustain¹, Airlangga Mardjono¹, Idham Riyando Moe¹, Evi Agustia¹, Teguh Mulia Aribawa¹, Adam Prana² and Bai Yanbing³

¹Directorate General of Water Resources, Ministry of Public Works and Housing, Pattimura 20, Jakarta, Indonesia
²Department of Geography, University of Canterbury, Ernest Rutherford 262, New Zealand
³School of Statistics, Renmin University of China, Zhongguancun St. 59, Haidan District, Beijing, China

Corresponding email: propezite.n.m@gmail.com

Abstract. Indonesia experiences floods which are rarely well documented in map form. Monitoring and estimating the impact of floods at almost the same time involves using a variety of techniques, from digital maps to using detailed surveys or remote sensing techniques. However, when using remote sensing techniques, the results depend on the data acquisition time (day or night) as well as by weather conditions. However, this obstacle can be overcome by using radar satellite imagery. The purpose of this study is to describe the surface of the water bodies affected by flooding in the Cidanau-Ciujung-Cidurian River Basin from 2016 to 2020. For this case study, the Sentinel-1 SAR Band data obtained from the ESA (European Space Agency) were used as research data. Data sets are retrieved before, during or after a flood and processed using SNAP Desktop. The result will display flood conditions using RGB color as a sign between wet areas (inundated) and dry areas (not inundated). Keyword: flood, map, radar image, river basin

1. Introduction
Flood disaster is one of the natural disasters that always occurs in various parts of Indonesia. A flood is a relatively high flow of water that extends beyond natural or artificial embankments in a river body. When the river bodies could no longer hold them, the water spread over the plains, causing problems for residents, crops, and public facilities. Dynamic natural events such as high rainfall, tides of seawater in major rivers, landslides, and silting due to sedimentation, as well as dynamic human activities such as the presence of inappropriate land use in the floodplain are some of the causes of flooding.

In dealing with floods, an initial assessment is needed, i.e. flood inundation maps. Current conditions of flood inundation maps can be obtained by local surveys using digital cameras or drones. Some various problems and uncertainties occur in making flood detection. The information on water bodies is an important source when examining floods. This problem can now be addressed with the latest advances in remote sensing. Satellite remote sensing has become more valuable for disaster monitoring and relief efforts from the beginning to the post-crisis of an event [1]. Since flood prevention, management, and emergency response is an important issue for policymakers, flood detection using remote sensing can improve the number of monitored areas in remotely accessed places or places without any monitoring program [2].
Satellite sensors could be grouped into two main categories: optical sensors and radar systems. The capability of wavelengths is one of the major differences between optical sensors and radar systems [3]. Optical sensors use lower wavelengths than radar systems. Radar systems can pick up spatial information on earth and are not affected by weather conditions due to Synthetic Aperture Radar (SAR). SAR is an active satellite system with the all-weather day-night capability of SAR sensors gives these a considerable advantage for flood mapping over sensors operating at visible or infrared wavelengths, as the latter are unable to penetrate the clouds that often accompany flood events. Flood water usually appears dark compared to the surrounding land because the smooth water surface acts as a specular reflector [4].

The flood mapping observations in this study used Sentinel-1 products. Sentinel-1 is the European Radar Observatory for the Copernicus joint initiative of the European Commission (EC) and the European Space Agency (ESA). The Sentinel-1 image product used is Sentinel-1 with the IW (Interferometric Wide Swath) format with level 1 GRD (Ground Range Detected) data. The IW format is the mainland acquisition, this mode has a range of 250 km with a spatial resolution of 5m x 20m (single display), and a small noise ratio. This technology has the advantage of being able to produce homogeneous image quality with almost uniform noise (Signal-to-Noise Ratio) which is almost uniform [5]. Due to the predominance of severe weather conditions during flooding time, freely available and regularly sampled Sentinel-1 imagery has great potential in producing flood information with high accuracy and high spatial resolution in six days intervals [6].

2. Study Area
The province in Indonesia that frequently floods is Banten with the largest river basin being Cidanau-Ciujung-Cidurian River Basin. It covers 7 administrative areas covering 5 districts and 2 cities with a total area of 412,518 ha. These administrative areas include Bogor Regency, Tangerang Regency, Pandeglang Regency, Serang Regency, Lebak Regency, Serang City, and Cilegon City. Cidanau-Ciujung-Cidurian River Basin has 34 watersheds, with the largest watersheds, namely the Ciujung watershed. The following is a table of watersheds in the Cidanau-Ciujung-Cidurian River Basin. The duration of the interval from Sentinel-1 affects the results of the images obtained by Sentinel-1, whether flood events can be recorded or not. In this case, the duration of flooding that has occurred in Cidanau-Ciujung-Cidurian River Basin is 5 days. The floods that occurred in the Cikalumpang River (Cidanau Watershed) in the period March 5th-9th, 2018 caused submerged hundreds of settlements, several hectares of rice fields, and submerged community gardens [7]. Therefore Sentinel-1 has the potential to capture images of previous flood events that have occurred in Cidanau-Ciujung-Cidurian River Basin in the period 2016 to 2020.

Table 1. Watershed in Cidanau-Ciujung-Cidurian River Basin.

| No. | Watershed  | No. | Watershed | No. | Watershed |
|-----|------------|-----|-----------|-----|-----------|
| 1   | Cidanau    | 13  | Cinangsi  | 25  | Cibako    |
| 2   | Cikalahi   | 14  | Cilasak   | 26  | Cigisik   |
| 3   | RunteunGirang | 15  | Cipetey   | 27  | Cibanten  |
| 4   | Cilegok    | 16  | Caringin  | 28  | Cirangrang|
| 5   | SetuLor    | 17  | Ciranggeng | 29 | Ciwaku   |
| 6   | Kopomasjid | 18  | Cinangka  | 30  | Cibunar   |
| 7   | Kali Malang| 19  | Sumur     | 31  | Ciujung   |
| 8   | Cigobang   | 20  | Bojonegoro| 32  | Cidurian  |
| 9   | Cicendo    | 21  | Candi     | 33  | Cirumpak  |
| 10  | Cigeblak   | 22  | Cikebel   | 34  | Cipayeun  |
| 11  | Cikebeletes| 23  | Cikubang  |     |           |
| 12  | Cibatu     | 24  | Cikaidau  |     |           |
Figure 1. Map of Watershed in Cidanau-Ciujung-Cidurian River Basin.

3. Research Objective
In the case of floods that have occurred in Indonesia, many flood maps use local surveys using digital cameras or drones, allowing uncertainty in the inundation areas due to the location of the missed floods. So that the flood inundation map made by this method has uncertainty and does not represent the actual conditions that occur in the flooded area. Based on that explanation above, the utilization of Sentinel-1 imagery data can be used in the development of flood inundation maps. This paper aims to provide an efficient tool solution in the development of flood inundation maps at the Cidanau-Ciujung-Cidurian River Basin that occurred from 2016 to 2020 using Sentinel-1 imagery data processed using the SNAP Desktop program.

4. Methodology
Generally, the study process is based on the stages that have been compiled and illustrated in the flow chart as shown in Figure 2.

4.1. Sentinel-1 Images Data
In this paper, only looking for flood events that have occurred in the Cidanau-Ciujung-Cidurian River Basin between 2016-2020. The date of the flood events was obtained from data from BBWS Cidanau-Ciujung-Cidurian, BNPB, BPPD, and othersources. The following are the search results for the date of the flood events that can be captured by Sentinel-1.

In analyzing 1 (one) inundation event, 2 (two) images of Sentinel-1 are needed, namely pre-event (conditions before flooding) and post-event (conditions during/after flooding). To analyze the 5 flood...
events, the pre-event conditions were used, namely on August 10th, 2016, and August 2nd, 2016. The following are images of the Sentinel-1 in 2 (two) pre-event conditions.

![Figure 2. Flowchart of Research.](image)

**Table 2. Pre-Events and Post-Events.**

| No. | Pre-Events       | Flood Events          | Post-Events          |
|-----|------------------|-----------------------|----------------------|
| 1   | August 10\(^{th}\), 2016 | December 6\(^{th}\), 2016  
April 25\(^{th}\), 2018  
January 1\(^{st}\), 2019 | December 8\(^{th}\), 2016  
April 26\(^{th}\), 2018  
January 3\(^{rd}\), 2019 |
| 2   | August 2\(^{nd}\), 2016 | December 25\(^{th}\), 2018  
January 1\(^{st}\), 2020 | December 25\(^{th}\), 2018  
January 1\(^{st}\), 2020 |

![Figure 3. Pre-Event Images](image)
4.2. Subset
Subset is the process of cutting the image to suit the location of the activity. This subset of the image cutting process is carried out to limit the scope of the image being processed only in the activity area, thus making the next process faster.

4.3. Calibration
Calibration is a radiometric correction process by performing a SAR calibration to provide an image in which pixel values can be directly related to the backscatter (backscattering of topography sensitive components of the image, rough surfaces, and ground cover that can reflect radar pulses) at the scene. Calibrated SAR images are essential for the quantitative use of SAR data. Radiometric correction is required so that the pixel value correctly represents the radar backscatter of the reflected surface. This is done when comparing SAR images obtained with different sensors, or obtained from the same sensor at different times, in different modes, or processed by a different processor.

4.4. Filtering
Filtering is a process to reduce or reduce the appearance of speckles on radar images. Speckles appear as black and white spots or commonly known as 'salt and pepper'. The filter is done with a 5x5 window. The bigger the window size, the smoother or "blurry" the image looks. The technique used is the Lee Filter to smooth out spots or speckles in the image by maintaining image sharpness and detail while reducing noise in the image.

4.5. Terrain Correction
Terrain Correction, namely the process of image geometric correction to adjust the image coordinates according to the coordinates of the earth. The geometric correction is done by determining the parameters and the VV amplitude band to be processed using SRTM as input to the DEM data, the data download is done automatically based on the SRTM DEM data, the GRD Sentinel-1 image is corrected and converted into geographic coordinates (lat / long, Datum WGS 84).

4.6. Overlay Image
This process is carried out by combining 2 pre-event and post-event images and projecting it onto a map system with the Stack menu, and performing RGB colors analysis which aims to display flood conditions using RGB colors as a sign between wet areas (flooded) and dry areas (not inundated).

5. Result and Discussion
In the case of flooding in the Cidanau-Ciujung-Cidurian River Basin, Sentinel-1 imagery data can capture several images. Figure 4 captures images on August 10th, 2016 is the basis for marking areas that are not inundated by floods. After analysis, the water body was detected by RGB. Red color to indicate flood inundation, and gray color to indicate land that is not flooded. Figures 5, 6, and 7 are the results of the analysis of flood events that occurred. Figure 8 captures images on August 2nd, 2016 serves as the basis for marking areas that are not inundated by floods. Figures 9 and 10 are the results of the analysis of flood events that occurred.
Figure 4. Pre-Event Images August 10th, 2016

Figure 5. Post-Event Images December 8th, 2016

Figure 6. Post-Event Images April 26th, 2018

Figure 7. Post-Event Images January 1st, 2018
The flood analysis shows that several watersheds are the places where floods occur most frequently. The watersheds are Cipayeun, Cirumpak, Cidurian, Ciujug, Cibunar, Ciwaku, Cirangrang, Cibanten, Cigisik, and Cidanau.
Later, BBWS Cidanau-Ciujung-Cidurian will get a clear picture of the flood events that occurred, so that the improvement steps both with physical and non-physical infrastructure development can be effective and efficient.

6. Conclusion and Recommendation

6.1. Conclusion

From the results of the studies carried out, there are several conclusions, among them are:

- This study provides a framework for detecting flood-affected areas using freely available and open-source SAR data, which is a low-cost and time-consuming solution for near real-time flood monitoring.
- The flood map developed from Sentinel-1 images is very clear and can show flood events in great detail.
- Flood events that occurred in Cidanau-Ciujung-Cidurian River Basin from 2016-2020 can only be captured 5 flood events. This indicates that the floods that occur are mostly flash floods, so that they are not taken by Sentinel-1.
- The watersheds that frequently flood are Cipayeun, Cirumpak, Cidurian, Ciujug, Cibunar, Ciwaku, Cirangrang, Cibanten, Cigisik, and Cidanau.

6.2. Recommendation

Based on the results of the study, we can conclude that remote sensing technology can provide precise information about flood conditions that occur, especially the Cidanau-Ciujung-Cidurian River Basin. So that it can provide a real picture to stakeholders in dealing with floods in Indonesia and can provide effective and comprehensive decisions. The advantage of this Sentinel-1 imagery is that it can provide clear images even in adverse weather conditions during flood times, and data can be easily retrieved, so it has great potential in producing flood information with high accuracy and high spatial resolution as well. But the lack of the data is periodic in intervals of six to twelve days. But with all the limitations that exist, the development of flood inundation maps using radar imagery can be an alternative solution that is good enough to provide an initial overview of flood events that occur.

Acknowledgments

Thanks to BBWS Cidanau-Ciujung-Cidurian, Directorate of Water Resources, Ministry of Public Works and Housing Indonesia that have supported this research activity.

References

[1] Ban H, Kwon Y, Shin H, Ryu H and Hong S 2017 Flood Monitoring Using Satellite-Based RGBComposite Imagery and Refractive Index Retrieval in Visible and Near-Infrared Bands Remote Sens. 9, 313

[2] Ogashawara I, Curtarelli M P and Ferreira C M 2013 The Use of Optical Remote Sensing for Mapping Flooded Areas Int. Journal of Engineering Research and Application Issue 5 pp 1956-1960

[3] Li Lin, Liping Di, Genong Yu E, Kang L, Shrestha R, Rahman Md S, Tang J, Deng M, Sun Z, Zhang C and Lei Hu 2016 A Review of Remote Sensing in Flood Assessment Conf. 5th International Conference on Agro-geoinformatics (Agro-geoinformatics)

[4] Mason D C, Bates P D, and Dall’Amico 2009 Calibration of Uncertain Flood Inundation Models Using Remotely Sensed Water Levels Journal of Hydrology 368, 224-235

[5] European Space Agency (ESA) 2019 SENTINEL-1 SAR User Guide Introduction

[6] Uddin K, Matin M A and Meyer F J 2019 Operational Flood Mapping Using Multi-Temporal Sentinel-1 SAR Images: A Case Study from Bangladesh Remote Sens. 11, 1581

[7] Rizaldi A, Riyando Moe I, Farid M, MuliaAribawa T, Bayuadjji G and Sugiharto T 2018 Study of Flood Characteristic in Cikalumpang River by Using 2D Flood Model MATEC Web of Conferences 270 Vol 8, 04010