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Rapid flood mapping with Sentinel-1 SAR images: A case study of Maritsa River

Ahmet Batuhan Polat*[1], Özgün Akçay [1]

[1]Canakkale Onsekiz Mart University, Faculty of Engineering, Department of Geomatics Engineering, Canakkale, Turkey

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ABSTRACT

Floods, one of the most devastating natural disasters, cause a large number of property and lives lost around the world every year. In general, the disaster caused by seasonal rains falling more than expected causes great damage to business lines such as farming. It is important to detect the flood areas as soon as possible due to occured flood disaster and provide aid to the damaged areas. In this study, it is aimed to quickly identify flood areas by using pre and during disaster event images obtained by remote sensing method. Then, these areas were visualized with the using of dB backscatter values. Radar images are used to detect flood areas due to low dB backscatter values on water surfaces. In this process using Synthetic Aperture Radar (SAR), the performances of different polarizations were also tested. Considering the results, the lowest backscatter value was obtained with VH polarization and it was demonstrated that the methods used in the study can be considered in rapid mapping of the flood areas.

1. INTRODUCTION

Maritsa River, is the partial of the border for Turkey and Greece. It starting from the Bulgaria and passes in Turkey, than it spills to Aegean Sea from the city of Edirne. When the rainfalls increased and causes to floods especially in the autumn and winter months, it is an important problem for the Greece and Turkey. Some severe floods occured in 2005, 2006 and 2007 in the area. Settlements and agricultural areas in the Turkey and Greece were heavily damaged from the floods (Derin 2020).

Flood is one of the most common destructive natural disasters on earth, causing loss of property and life (Li et al. 2018; Manavalan 2017). Remote sensing and satellite images are a common method for analyzing flood areas resulting from disasters, as they are cost-effective and provide real-time monitoring (Capolongo et al. 2019; Giustarini et al. 2016).

Remote sensing systems to be used for monitoring flood areas can be examined under two different headings: these are active and passive systems. Passive systems consist of optical satellites and contain rich information in image bands, so they have more preferable results in land cover mapping (Goffi et al. 2020). However, despite these results, optical satellite images frequently do not produce the desired results during flood disasters, because of the rain clouds restrict satellite view during the disaster period (Huang & Jin 2020). SAR images, which is an active system, are does not affect from the weather conditions. For this reason, it is the best remote sensing method to be used in cloudy weather conditions and to detect on the surface continuously (Shen et al. 2019; Marzano et al. 2011; Schumann et al. 2009). Also, smooth water surfaces can be easily detected in radar images. This is because the high scattering on a flat surface does not ensure that the returning microwave energy cannot be detected by the receiver (Martinis & Rieke 2015). Therefore, water surfaces perceived as flat by the sensor have more distinct dark pixels than different land surfaces.

SAR images have been used for years with different methods such as active contour models, threshold value approach and change detection to gather information and mapping in the flood events (Horritt et al. 2001; Hostache et al. 2012; Brivio et al. 2002). Among these methods, the use of threshold value filters all pixels to show backscatter values lower than a certain threshold value, giving fast and reliable results (Townsend 2002; Pulvirenti et al. 2012). In this way, flood mapping can be done quickly in floods that occur as a result of natural disasters and studies can be carried out in the relevant areas as soon as possible. Also Aciksarı and Akcay observed in their study in 2018 that the combined use of

* **Corresponding Author**

*(abpolat@comu.edu.tr) ORCID ID 0000-0002-7495-1998
(akcay@comu.edu.tr) ORCID ID 0000-0003-0474-7518

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vertical and horizontal polarization increased the information perceived from the SAR image (Açıksarı & Akçay, 2018).

The aim of this study is to examine the back scattering values and present them visually with the threshold value in order to quickly flood mapping as a result of the floods in the Maritsa River. The images used were obtained on two different dates, before and during the flood. The histogram graph, minimum, maximum and average backscatter values of the scattering values were compared to determine the flood areas. In addition, VV and VH, which are different types of polarization in SAR images, were examined separately and the results were presented. Thereby, it has been tried to determine an optimal method to quickly identify flood areas with SAR images in sudden floods.

2. METHOD

Preprocessing steps were carried out by imaging the SAR images taken before and after the event with different polarizations as VV, VH and VV+VH/2. Afterwards, backscatter values were obtained from the SAR images and the flood areas were determined by applying the threshold value. Histogram graphics were examined separately for each image and polarization, and the mean and extreme values were compared.

2.1. Dataset and Study Area

The SAR images used for the study were obtained from the Sentinel-1A radar satellite provided free of charge by the European Space Agency(ESA). Sentinel-1 allows viewing SAR images in four different C-band imaging modes, with single or double polarization (Torres et al. 2012). Also, it has a spatial resolution up to 5 m, a coverage area of up to 400 km, and it passes through the same region in a short time. The acquisition dates of satellite images are given in Table 1.

Table 1. Image Acquisition Dates

Sentinel-1 SAR Image
30 October 2020 (Pre Event)
3 February 2021 (During Event)

As a study area, Maritsa River area has been selected which in the west of Turkey and has a border with Greece. The reason for being chosen as a study area is to affect by floods almost every year. The study area is shown in Figure 1.

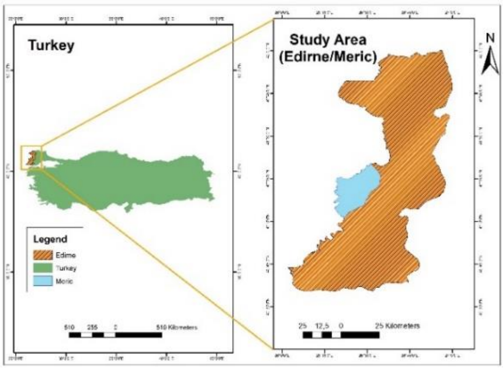

Figure 1. Study Area

2.2. Data Preprocess

Since raw SAR images are not suitable for direct use, they must go through a number of preprocessing steps. First, the orbit information of the SAR images were updated. Later, thermal noises in the images were removed. Than, the noises occurring in the image borders were removed. With the calibration performed after this process, the pixel values were directly associated with the radar backscatter. The Speckle Filter was applied to remove the speckles that negatively affect the image with the newly formed Sigmaσ values. While applying the Speckle Filter, a 7x7 size Lee Sigma filter was used. Finally, the terrain correction of the image was made and the corrected surface model was obtained. Preprocessing steps are shown in Figure 2.

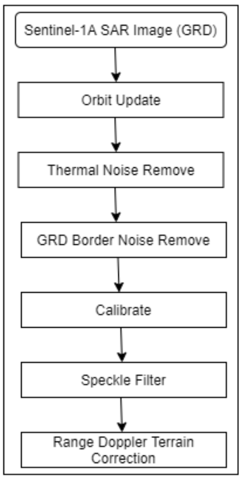

Figure 2. Preprocess Steps

After the preprocess steps, the backscatter values were filtered by using of the threshold values. Finally, the flood areas were obtained with filtered backscatter values for before and after the disaster. The images taken with different polarizations after the preprocessing steps are finished are shown in Figure 3.

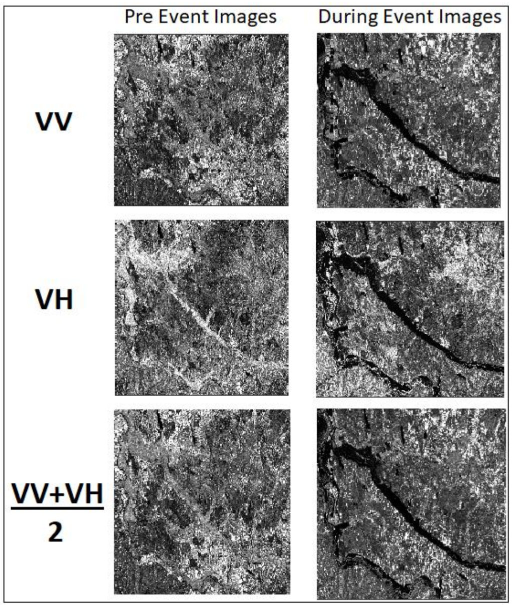

Figure 3. The acquisition of images obtained before and after the disaster in the study area with different polarizations

3. RESULTS

The extreme and average values of the backscatter values obtained from the images pre and during the event as a result of the operations performed are given in Table 2 and Table 3.

Table 2. Backscatter values of the image taken on October 30, 2020 (Pre event)

dB Values(Pre Event)	Minimum Value(dB)	Maximum Value(dB)	Mean Value(dB)
VV	-25,796	9,063	-8,9211
VH	-27,451	3,543	-16,8406
(VV+VH)/2	-25,906	6,265	-11,2236

Table 3. Backscatter values of the image taken on February 30, 2020 (During event)

dB Values (During Event)	Minimum Value(dB)	Maximum Value(dB)	Mean Value(dB)
VV	-26,547	6,22	-10,4023
VH	-27,647	-1,552	-18,0592
(VV+VH)/2	-26,729	3,881	-12,6127

Considering the backcatter values, it is seen that the lowest backscatter value is obtained from the image taken with VH polarization during the event with -27,647 dB value. Likewise, according to the average backscatter values, the lowest backscatter value was obtained from the VH polarization during the event. Histogram graphs of the backscatter values for all images are given in Figure 4.

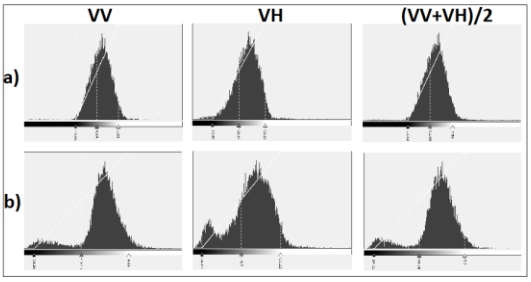

Figure 4. a) Histogram graphs of images taken pre event b) Histogram graphs of images taken during event

Finally, in the VH polarized image where the lowest backscatter values were obtained, the threshold value was applied to the dB backscatter values, and the flood areas were visualized for pre and during the event. The image of the flood areas is shown in Figure 5.

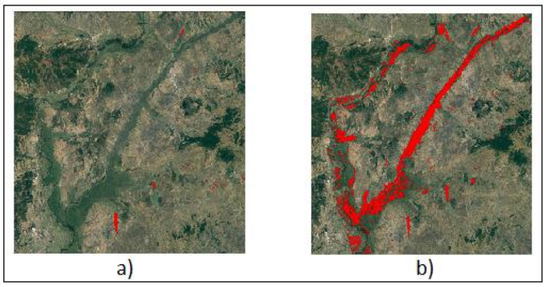

Figure 5. a) Pre event flood areas with the VH polarization b) During the event flood areas with the VH polarization

4. DISCUSSION

According to the dB backscatter obtained, the average values in all polarizations in the image taken during the event decreased. The reason for this is the increase in water areas and the low backscatter values obtained on water surfaces.

As a result of the comparisons made, the lowest backscatter value at minimum dB values was obtained from the image taken with VH polarization during the event with -27,647 dB. The highest minimum dB value was obtained with -25,796 dB as a result of the acquisition made with pre event VV polarization image. In average dB backscatter values, the value change in the image acquired with VV polarization was approximately 16.6%, in the image acquired with VH polarization approximately 7.2%, and a change of approximately 12.38% was observed in the acquisition using VV and VH polarizations together.

VH polarization more specifically determines the flood areas because it sends the signal vertically to the work area and receives the transmitted signal horizontally while it is received. By this way, different textural features are gathered from the image and different values are obtained from the reflected backscatter values.

5. CONCLUSION

In this study, one of the fastest methods for detecting the flood areas after sudden floods with SAR images was examined and the results obtained were analyzed. Optical satellite images are not always available during a flood disaster. The reason for this is the meteorological conditions that occurred during the event. Another advantage of using radar images for flood analysis is that due to the flat perception of water surfaces, smooth back reflection cannot be obtained and backscatter values are perceived as very low, and this advantage has been demonstrated in the study. As a result of the study, it was seen that the image acquisition polarization that most distinctly detected the flood areas was VH. The worst result was obtained from the image taken with VV polarization.

According to the results obtained in the study, SAR images provide the necessary facilities for the detection and analysis of the areas affected in a rapidly happening natural disaster such as a flood. In this way, threshold values can be determined from histogram graphs with the help of dB backscatter values in SAR images used for rapid flood mapping and areas can be displayed on the map. In future studies, it is aimed to establish the relationship of the work carried out with geographical information systems in the areas where flood disasters are experienced regularly. With this relationship, it is aimed to make risk analysis and discuss the precautions in the relevant region in order not to be affected by the destructive effects of flood waters.

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