

# FLOOD MONITORING USING SENTINEL-1 SAR DATA: A CASE STUDY BASED ON AN EVENT OF 2018 AND 2019 SOUTHERN PART OF KERALA

SP.Dhanabalan <sup>a\*</sup>, S.Abdul Rahaman <sup>b</sup>, R.Jegankumar <sup>c</sup>

<sup>a,c</sup>Department of Geography, School of Earth sciences, Bharathidasan University, Tiruchirappalli- 620 024-  
dhanageo.1996@gmail.com, jegankumar@bdu.ac.in

<sup>b</sup>Department of Geography, Bangalore University, Bengaluru, Karnataka -560 056- abdulatgeo@gmail.com

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## ABSTRACT:

Flood is a natural hazard influenced by rainfall and dam collapse, which propels release of enormous amount of water. In the last two decades flood is the second largest natural hazards occurred worldwide, which caused serious damage to life properties, settlements and economic activities. Flood mapping is a process that is useful for assessment and reduces the risk factor during the flood. An effective monitoring of flood prone area is necessary to handle GIS techniques and without remote sensing data it is difficult to identify the flooded area in this study Microwave remote sensing plays a lead role in natural hazards, here Synthetic Aperture Radar (SAR) data is the best way for monitoring flood hazards. In this study Southern part of the Kerala is chosen as the study area, In August 2018, during the south west monsoon due to heavy rainfall a severe flood affected the southern part of Kerala which saw a 37% increase in the rate of normal rainfall. The objective of the study is to find the flood zone area using SAR data and estimate the flood occurrence over a period of time. However a satellite imagery of optical data is used to analyse the pre and post event of flood, but during a heavy rainfall, cloud may interrupt the data acquisition. SAR satellite imagery from Sentinel-1A is a cloud penetrating data available in all kind of weather conditions during day and night time, which provides a good source of high resolution data sets. To identify the flood affected area an adapted technology of threshold methodology developed by using SAR data and change detection for the year 2018 and 2019, will illustrate flood extended part in southern part of Kerala. The result shows the estimation of flood extended part of the study area and the damages occurred during a flooded time period of post and pre event, vulnerability assessing of crop and agriculture is to obtain an intensity of the damaged areas which is closely associated with the river channel, the Polarization displays a similar sequence for amount of flooding. The study helps to find the reason of flood extent and to equip with better planning for risk reduction and management during a flooding period.

## 1. INTRODUCTION

Floods are frequently occurring natural hazards that cause great damage to lives and property (Martinez, & Landuyt, et al., 2019). The timely information of the flood occurrence and impacts are helpful for the government to act immediately to the emergency response. The rapid estimation of the spatial extent of flooding over large areas provides a key data source for assessing the disaster risk and spatial planning (Dumitru, et al., 2015). Remote sensing and satellite imagery plays an important role in monitoring and flood mapping (Li, Y. et al., 2018). Optical remote sensing has been used for dynamic flood monitoring based on the low reflectance of water in the infrared bands and high reflectance in the blue/green bands (Twele, et al., 2016). But however flood occurs in very bad weather conditions of heavy rainfall with intense cloud coverage of the affected area, while in this condition optical remote sensing not suitable to attain the accurate condition due to lack of cloud-free, high-quality images and also in optical remote sensing it difficult to detect the water under the vegetation cover (Pricope, et al., 2013). Synthetic Aperture Radar (SAR) datasets are very beneficial in observing flood conditions, it actively emits electromagnetic waves, which are unaffected by the weather and time of day, and can be used to detect flooding in vegetated or urban areas because of its high penetration capability (Mason, et al., 2012). Synthetic Aperture Radar is used for flood monitoring and management because it has a high spatial resolution, the Sentinel-1 satellite comprises a two radar of Sentinel-1A and Sentinel-1B acquires a data for massive volume of global level (Potin et al., 2015; Torres et al., 2012), SAR image has a VV/HH/VH/HV polarization by the observation VV polarization is classify the wetlands and water bodies ( Baghdadi et al., 2001; Wang et al., 2011) Thresholding-based methods, image segmentation, statistical active contouring, rule- based classification and data fusion approaches are the SAR

based techniques for flood detection and monitoring (Pradhan, 2016). Among these, thresholding-based methods are the most commonly used for flood detection; it was most efficient method and provides reliable results in near real time mapping (Amitrano, et al., 2018). In August 2018, during the southwest monsoon due to heavy rainfall a severe flood affected the southern part of Kerala which shows a 37% increase in the rate of normal rainfall as per the report of Central Water Commission (CWC 2018, 2019) in overall comparison between the years of 2019. The high rainfall during the southwest monsoon causes a severe flood in the state, about 445 people were died and 14 missing cases in the year of 2018, a comparison between 2019, 121 people died and 59 missing cases were filed, due to heavy rainfall 35 dams were opened out of 54 in first time of the history, the rainfall causes flood and landslides in hilly regions of the state (Vishnu et al., 2019). Kerala was significantly affected by heavy rainfall of monsoon period about 2515.7mm of annual rainfall in 2018 and 2309.8mm in 2019. Nearly 23.34% excess of rainfall august in 2018 and 12.72% in 2019 during the southwest monsoon, this situation resulted the severe cause of flood, out of 14 districts 13 were affected by the flood (CWC 2019; Mishra et al., 2018; sudheer et al., 2019). In this scenario, the present research work have the following objectives to find the flood zone area using SAR data and estimate the flood occurrence over a period of time, the study adopts a remote sensing data of Sentinel-1A SAR data and Sentinel-2. The flood inundation area were delineated from Sentinel-1A and the permanent water body was delineated by using Sentinel-2 Multi Spectral Image of optical data, the identification of flood area is helps to understand and estimate the vulnerable zone during a disaster. This research aims to delineate the flooded area using simple techniques that brought out a freely available SAR data.

## 2. STUDY AREA

Kerala state is situated in India's tropical Malabar Coast, nearly it has a length of 600 km long stretch Arabian Sea shoreline and the

southern part of Kerala is chosen as a study area with a network of major rivers including Manimala, Pamba and Achankovil. March to May end is a hot season, then the southwest monsoon continuous still the beginning of October, from October to the end of December is Northwest monsoon season and the January and February is a winter season. Summer month is not comfortable because of high temperature and humidity in the month of March to May, the state has extreme humid condition due to the Arabian Sea in the west. The south west monsoon in Kerala was started in middle of the year months between May to June, the average temperature during the season maximum of 30°C and minimum 19°C, average rainfall during the season is 2250mm to 2500mm. The Northeast monsoon in Kerala was started in the month of October and November up to December average temperature in the season maximum 35°C and minimum 29°C and the average rainfall during a season is 450mm to 500mm as per the report provided by IMD (Indian Meteorological Department Thiruvananthapuram). The study area lying between 9°47'55.9'' - 9°20'32.1''N latitudes and 76°20'9.1'' - 76°36'6.8''E longitudes, a coverage of Sentinel-1 satellite is ascending and descending passes in the study. The area cover is about 2413sq.km. The study area has a rich comprises of wetlands, mangroves, urban, rural, and agricultural land, a Vembanad lake also passes the study area fed by major rivers and this lake acts as a main source of paddy cultivation field and fishery farms. A heavy rainfall with sudden release of dam water, caused the enormous flood event in the southern part of Kerala. Figure (1) shows the study area.

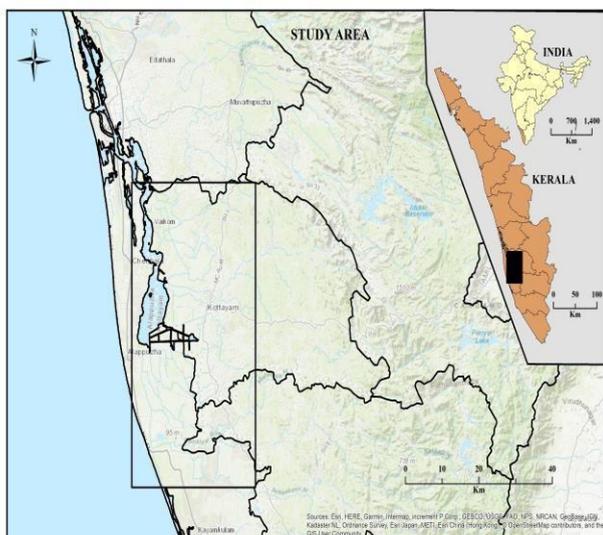


Figure 1. Study Area

### 3. DATA AND METHODOLOGY

#### 3.1 Datasets

In this study Sentinel level-1 Ground Range Detected (GRD) data was acquired in Copernicus open access hub (European Space Agency). The mission of Sentinel level-1 comprised with two polarization of VV/VH performing C-band Synthetic Aperture Radar (SAR) frequency of 5.404 GHz available in all kind of weather situation of day and night time with a revise period of 12 days. This SAR image was chosen to analyse the 2018 and 2019 flood event in the Kerala state to understand the flood extended path. Table 1 provides details of SAR data characteristics and data

acquisition. The sentinel level-2 optical data with Ortho-rectified, calibrated, geometric corrected and data was acquired to estimate the permanent water body. PERSIANN (Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks) CCS (Cloud Classification System) data acquired in CHRS (Centre for hydrometeorology and remote sensing) portal for global level and here it is chosen as an Administrative unit of Kerala with a district level annual rainfall for the year of 2018 and 2019 data acquisition was carried out.

#### 3.2 SAR data pre-processing

The sentinel-1 GRD raw data was taken for a pre-processing in Sentinel application platform (SNAP), the software provided by the European Space Agency (ESA). SNAP software is exclusively for pre-processing of SAR data, the data were processed by various steps as follows: Applying orbit file to precise the data for better geocoding progress, the radiometric calibration toolbox is used to convert the pixel into radar backscatter coefficient, an image intensity values are converted into sigma naught (Vanama, V. S. K., et al., 2021) Then the radar backscatter image were multi-looked with 7x7 of azimuth and range which results in 30m pixel size. The multi-looked image has taken for further step of speckle filtering to reduce noise in SAR image, after that process the image implement to range topler terrain correction for back geocoding. The terrain corrected image has a pixel size of 30m x 30m in linear scale using 1arc sec SRTM DEM, next the geocoded SAR image were mosaicked and subset to the required study area for further analysis. The post processing of permanent waterbody extraction and flood inundation by ArcGIS platform. The raw image and pre-processed image shown in figure (3).

#### 3.3 Permanent Water Body (PWB) Extraction

To find the flood area the permanent water body (PWB) were masked to underestimate purpose Normalized Difference Water Index (NDWI) algorithm will detect the PWB and dry land, the equation for NDWI is shown in (Eq.1). Here multi spectral image of Sentinel-2 has used to find the PWB in the flooded region, the pre-flood image of 2018 February 10 and 2019 February 5 has chosen to find a PWB. After the estimation of PWB were masked and converted into vector file format as a shapefile, the masked pixels which respects only Vembanad lake, because it is an major perennial water body. Then the shapefile was overlay in SNAP software to compute the water body for estimation of flood extended area and band math statistical approach will find the threshold value of flood affected area through the pixel wise in NDFI (Normalized Difference Flood Index) with ROI mask in the flooded area of temporal SAR data sets. Figure (2) shows the methodology of the study.

$$NDWI = (NIR - SWIR) / (NIR + SWIR) \text{ Eq. 1}$$

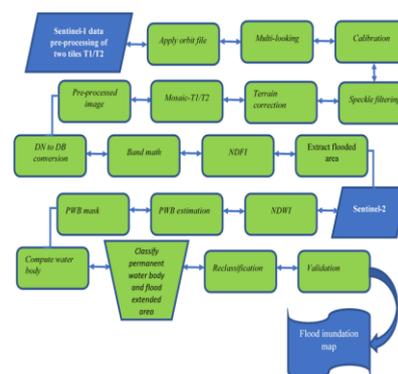


Figure 2. Methodology

Table 1. Data Type & Data Acquisition

Acquisition Date	Satellite	Spatial Resolution & pixel spacing	Polarization/ Bands	Pass	Flood condition
2018/02/10	Sentinel-1	20×22m 10×10m	VV	Descending	Pre-flood
2019/02/05	Sentinel-1	20×22m 10×10m	VV	Descending	Pre-flood
2018/08/21	Sentinel-1	20×22m 10×10m	VV	Descending	Post-flood
2019/08/10	Sentinel-1	20×22m 10×10m	VV	Descending	Post-flood
2018/02/10	Sentinel-2	10×10m	B3 & B8	-	Pre-flood
2019/02/05	Sentinel-2	10×10m	B3 & B8	-	Pre-flood

Source: Compiled by Author (ESA Copernicus Portal)

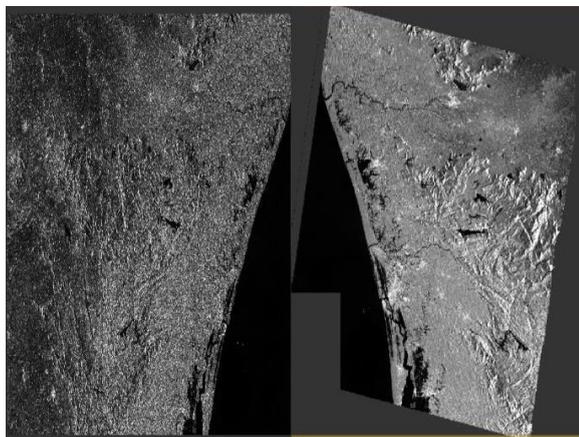


Figure 3. Pre-Processing before & after, first image is a raw data and the second one is Pre-processing image

#### 4. RESULTS AND DISCUSSION

Two different dated of sentinel-1 images was taken and pre-processing were done, a backscattering analysis is processed on VV polarization to identify the land cover and flood extended path. The image pre-processing is primary step to analysis the data set, after the pre-processing of acquisition data sets was look better resolution to identify the different land features, a backscattering analysis will shows the flooded area, water bodies, wetland with a sequence of backscatter reflectance. A pre-flood image is taken to identify the serious changes in the land surface and agricultural area gives low backscattering values as well as in post flood also due to some specular reflectance, change detection may estimate the flooded area and pre-flooded area of completely dry, the identified flood inundation area features such as, roads, settlements, open space area, agricultural lands on 2018 August 21 as well as same in 2019 August 10 also. In the pre-processed image shown in figure (4&5) shows the dark colour as a water features and grey colour depicts the land covers. The backscattering analysis will demonstrate the water body, flood extended areas and therefore to found the optimized flooded area ( $\mu_{\text{water}} + \sigma_{\text{water}}$ ) 0.04 is a threshold value, the pixel below this value are flooded areas. The threshold value is extracted by NDFI with ROI mask of flood through pixel vies, the radar backscatter coefficient analysis is a trend to identify the different land cover characteristics and results the flood inundated area of two different dated Sentinel-1 of pre and post event. Polarization displays a comparable series for amount of flooding throughout the study period, a VV polarization and the backscatter values for land and water classes ranged between  $-0.9$  to  $0$  dB and  $-21$  to  $-18$  dB correspondingly. The figure 4 and5 shows a pre and post event of flood affected areas in 2018 and 2019 in the study region which is highlighted in blue color

rectangle box.

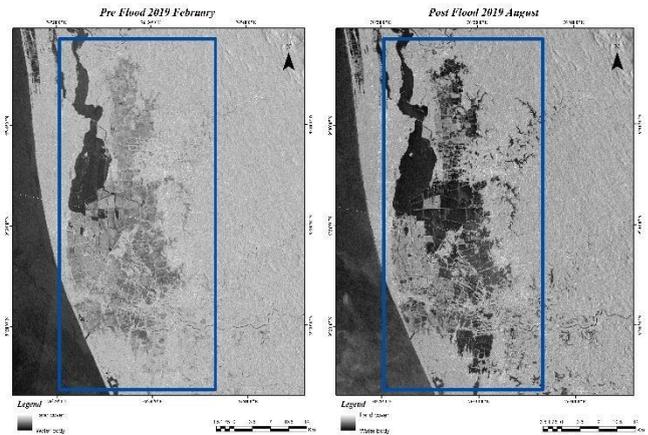


Figure 4. Pre & Post Event of Flood in 2018

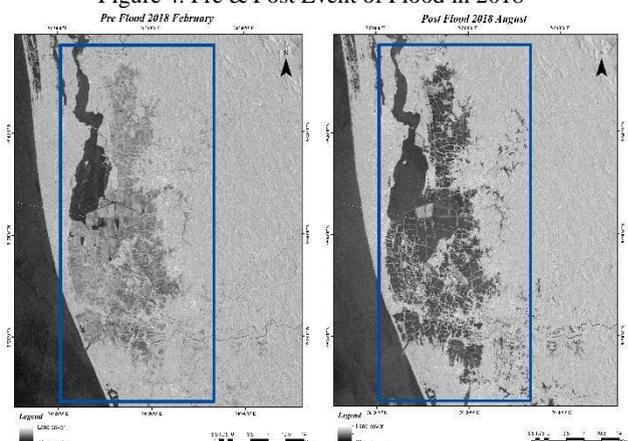


Figure 5. Pre & Post Event of Flood in 2019

The delineation of water pixels to identify the total flood inundated area and masked the permanent water body to differentiate the changes over a study area. The NDWI was processed to find the permanent water body shows in Fig(6) here the PWB were extracted to estimate inundated area of pre-existing features, the black colour depicts the land cover and the white colour as a water body. Figure (6) Shows a permanent water body in 2018 and 2019.

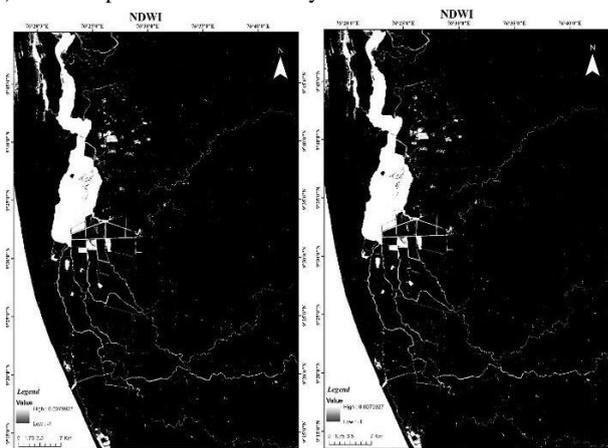


Figure 6. Permanent Waterbody in 2018 & 2019

Land, agricultural areas has a low reflectance of  $(-1)$  value and the water body has a high reflectance of  $(0.079)$  in 2018 February 10 before the flood event, here Vembanad lake is delineate as a PWB, this techniques is carried out to shows the permanent inundated area

and freshly inundated area. A major reason for the flood is southwest monsoon of 2018 started in June, in this study southern part of Kerala were chosen to find the flood extended path over a period of time. In a comparison between the year of 2018 and 2019; 2018 has a higher cumulative annual rainfall of (523mm) and low rainfall of (128mm), as 2019 data comparison shows a higher cumulative annual rainfall of (346mm) and low rainfall of (118mm) as shown in figure (7). Mostly southern part of Kerala depicts a higher amount of annual rainfall and 2018 has a higher annual rainfall of rate to comparison between 2019 as per the PERSIANNCCS global data.

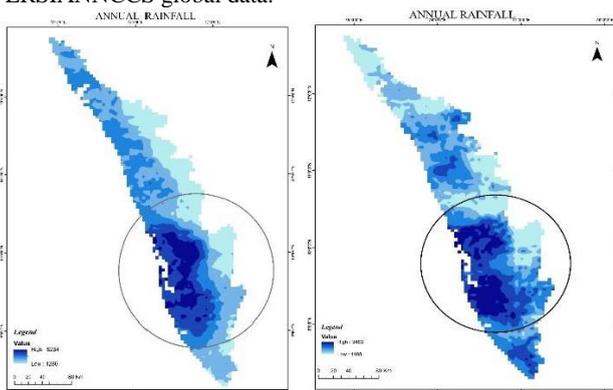


Figure 7. Annual Rainfall 2018 & 2019

The heavy rainfall event triggered the flood, after 21 August 2018 the flood affected area is about 398sq.km and 349sq.km in 2019 as per the report of Central Water Commission (<http://cwc.gov.in/>) concurrently opening of reservoirs causes higher flow of water in Vembanad lake. The agricultural pattern of the study area was adversely unscientific method of cultivation practices and land utility like wetland to dryland conversion, then the river channel area were constructed into built-up land. The improper drainage system also a major reason for flood inundation in the accidental situation, so that major damages was occurred mostly in agricultural crop land and residential regions. In August 2018 during the south west monsoon due to heavy rainfall a severe flood affected a southern part of Kerala which shows 37% increase in the rate of comparison between 2019, so it indicates 2018 has been mostly affected by the flood event. Figure (8) shows a flood inundation map of 2018 and 2019.

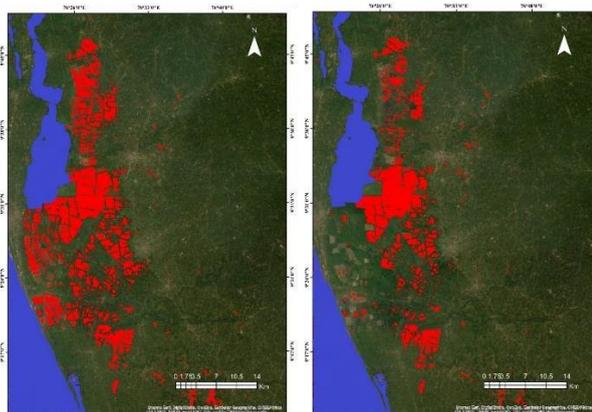


Figure 8. Flood Inundation Map for 2018 & 2019

## 5. CONCLUSION

Sentinel-1 SAR satellite was launched with a specification of C-band sensor for the purpose of natural events happen in the

environment and various applications, the availability of SAR data is free of cost with a high resolution of 10m primarily. SAR data is a cloud penetrating data available in all kind of weather condition as well as day and night time, it is an efficient tool for mapping a natural disaster with a temporal resolution of 12 days repeat pass. In the time of disaster acquisition of image depends upon the satellite pass availability, Sentinel-1 image acquisition is descending direction pass for southern part of Kerala and Southern India. Two images of Sentinel-1A and Sentinel-1B acquire an ascending and descending pass direction during the flooded day on 2018 August 21 and 2019 August 10, flood inundation mapping using a SAR data is necessary in the event of Southern Kerala. This study demonstrates the VV-polarization of SAR data which estimates the flood extended path using simple techniques, a band math statistical approach will estimate the threshold values in NDFI with ROI mask in the flooded area of temporal SAR data sets, this demonstration technique is universally applicable and the visual interpretation of results which emphasizes the effect of methodology. The result shows the estimation of flood extended part of the study area and the damages occurred during a flooded time period of post and pre event, vulnerability assessing of crop and agriculture is to obtain an intensity of the damaged areas which is closely associated with the river channel, the polarization displays a similar sequence for amount of flooding. The study helps to find the reason of flood extent and to equip with better planning for risk reduction and management during a flooding period.

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