# Flood Mapping and Monitoring using Microwave Remote Sensing

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**Abstract**

The northern region of India experienced intense rainfall during the initial fortnight of July, attributed to the dynamic interplay between Western Disturbances and the Monsoon trough. A notable event occurred between July 9 and 13 when water was discharged from the Hathnikund Barrage, reaching a peak discharge of approximately 3.79 lakh cusecs on July 11. The consequential rise in the water level of the Yamuna River surpassed the historical high-water mark of 207.49 meters recorded in 1978, reaching a height of 208.66 meters. This meteorological event inflicted significant flooding impacts on Delhi, leading to the provision of shelter to around 16 thousand individuals in relief tents. The study area consists of Delhi and five adjoining districts, Sonepat and Faridabad from Haryana, and Baghpat, Ghaziabad, and Gautam Budh Nagar from Uttar Pradesh. The optical satellite data is not very useful in adverse weather conditions and extensive cloud cover. Here, the implementation of synthetic-aperture radar (SAR) technology proved advantageous, penetrating through cloud cover and atmospheric haziness to systematically map flood inundated areas. Leveraging the literature that recommends the use of VH and VV radar polarizations (VH+VV) for urban flooding assessments, this study employed Histogram Thresholding to extract permanent waterbodies and flood inundation zones from the VH+VV band. The resultant flood map was scrutinized to uncover temporal and spatial flood dynamics, shedding light on the evolving extent of inundation. Damage was assessed with respect to LULC class, focusing on the agricultural land and infrastructure. These insights serve as a foundation for effective relief planning and flood management strategies. The analytical framework of this study was supported by ArcGIS Pro and the ArcGIS Python API, bolstering comprehensive spatial analysis, and contributing to informed decision-making in flood-prone regions.

**Keywords:** Flood Mapping; Sentinel-1; Microwave Remote Sensing; Damage Assessment

**Introduction**

Flood comes under one of the most costly and frequent natural disasters. National Institute of Disaster Management (NIDM) defines flood as "an excess of water (or mud) on land that's normally dry and is a situation where in the inundation is caused by high flow, or overflow of water in an established watercourse, such as a river, stream, or drainage ditch; or ponding of water at or near the point where the rain fell. This is a duration type event. A flood can strike anywhere without warning, occurs where a large volume of rain falls within a short time." (Kanda & Aggarwal, 2008)

In the past studies flood mapping methods were based on aerial observations and ground surveys, but when the flood is widespread, then these methods are time taking and costly. Furthermost timely aerial observations can be very difficult due to bad (cloudy) weather conditions. An alternative option is use of satellite remote sensing data where optical sensors were used to acquire data which were on board spacecraft used to map inundated areas (P.A. Brivio, 2002). Inundated areas can be identified using flood mapping techniques which will give flood extent of the study area. Time series analysis can be done for showing the changes in the inundated areas.

**Materials and Methods**

*Study Area:* The study area consists of Delhi and five districts. Five districts are Sonepat & Faridabad from Haryana and Baghpat, Ghaziabad and Gautam Budh Nagar from Uttar Pradesh. Figure 1. shows study area map of this analysis.

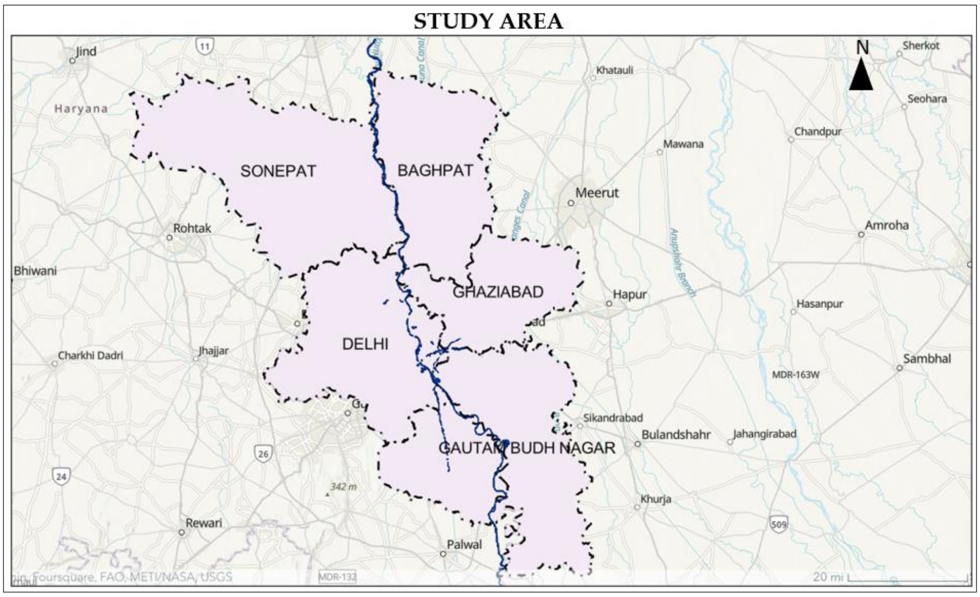


**Fig. 1** Study Area Map.

North India faced severe rainfall in the first two weeks of July due to the interaction between Western Disturbances (a low-pressure system originating from the Mediterranean region) and Monsoon trough (a low-pressure zone located in East west direction from Northwest Rajasthan towards the Bay of Bengal). From 9 to 13 July water was released from Hathnikund Barrage, on 11 July highest discharge was released from the barrage which is 3.79 lakh cusecs approximately.

*Data Used:* Sentinel-1 GRD data was used for the creation of flood inundation maps, as SAR is capable to penetrate clouds and gives accurate and high resolution (10m) results. Land Use Land Cover (LULC) classification map was created from Sentinel 2 L2A imagery using Land Cover Classification (Sentinel-2) pretrained model from ArcGIS Living Atlas of the World for May 2023 imagery.

*Methodology:* Sentinel-1 data was downloaded for four dates August 23rd, 2017; August 30th, 2018; August 20, 2019; July 26th, 2020 each representing its year scenario. Pre-processing of Sentinel-1 data was done on ArcGIS Pro.

Sentinel-1 GRD imagery was used for this study. Literature suggests sum of VH and VV (VH+VV) works best for urban flooding. The permanent waterbodies and flood inundated areas were extracted from VH+VV band using Histogram Thresholding.

Firstly, Sentinel-1 imageries were clipped with the study area extent. To get the radar backscatter values, radiometric correction was carried out, speckle filtering was applied to remove the salt & pepper effect from imageries. Geometric correction was applied to remove the height related noise which was introduced due to side looking SAR sensors. The permanent water bodies were removed using the water class extracted from LULC map.

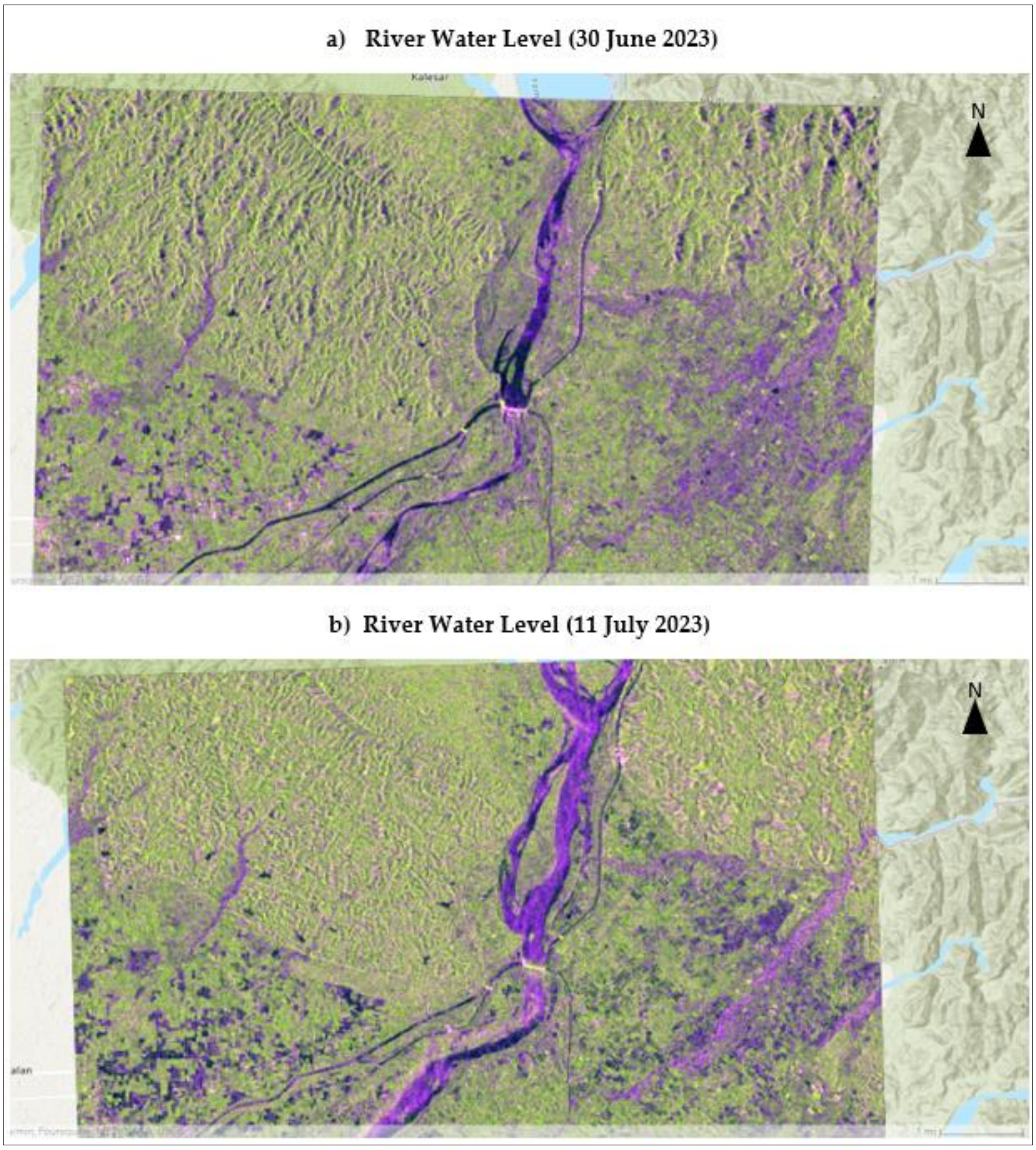


**Fig. 2** Hathnikund Barrage water level using Sentinel-1 imagery a) 30 June and b) 11 July.

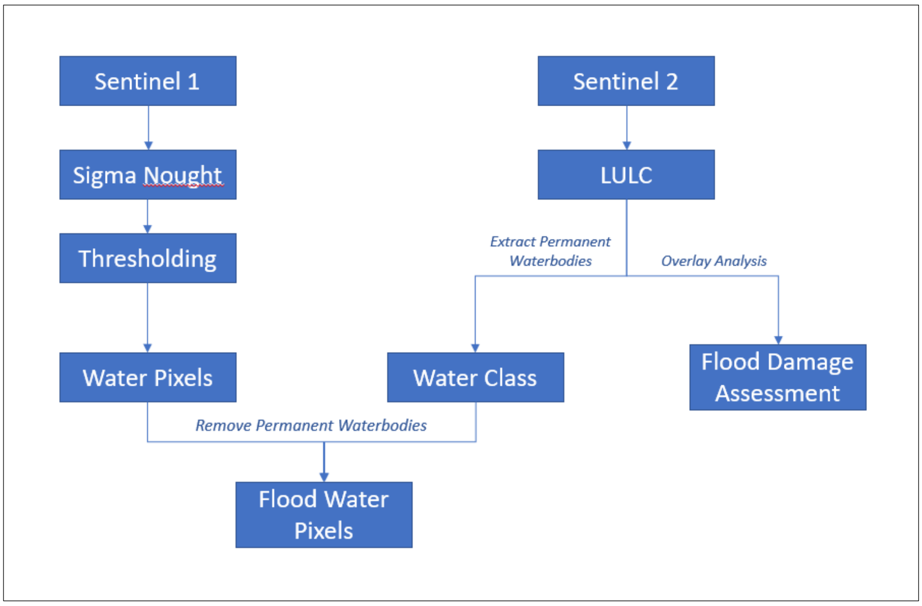


**Fig. 3** Methodology.

A threshold value was select for each imagery using its histogram. Using the threshold value binary images were created which represents water (Value=1) and non-water (Value=0) pixels. The binary rasters were converted to polygons and these polygons were used for the creation of flood inundation maps.

**Results & Discussion**

*Flood Inundation Mapping:* The inundated area was extracted from the SAR imagery using threshold method. The flood extent maps for the following dates: July 12, 2023 and July 16, 2023 shown in Figure. According to the analysis July 12, 2023 has the highest flood level, literature also suggests the same.

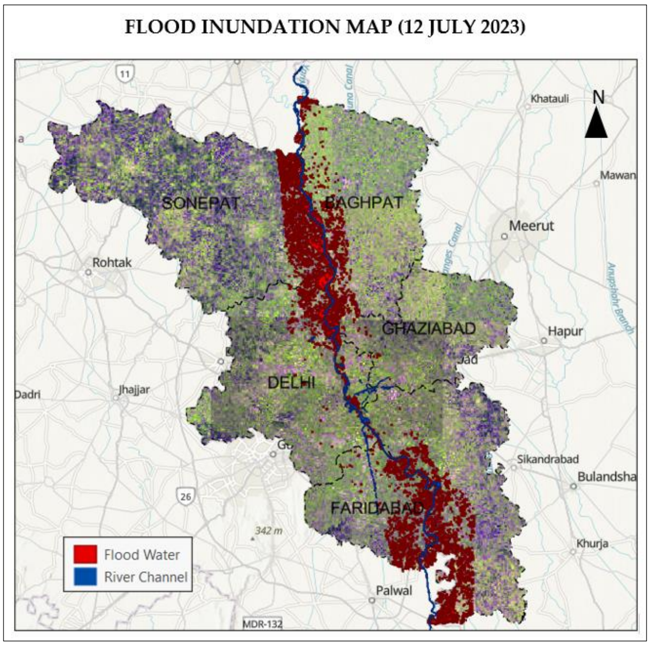


**Fig. 4** Flood Inundation Map for 12 July 2023.

Due to the release of water from the Hathnikund Barrage on 11 July, 2023 the water level in the Yamuna reached 208.66 meters, which is the highest since the 1978 floods which was 207.49 meters. Pixels in red colour and blue colour represents the pre flood river channel.

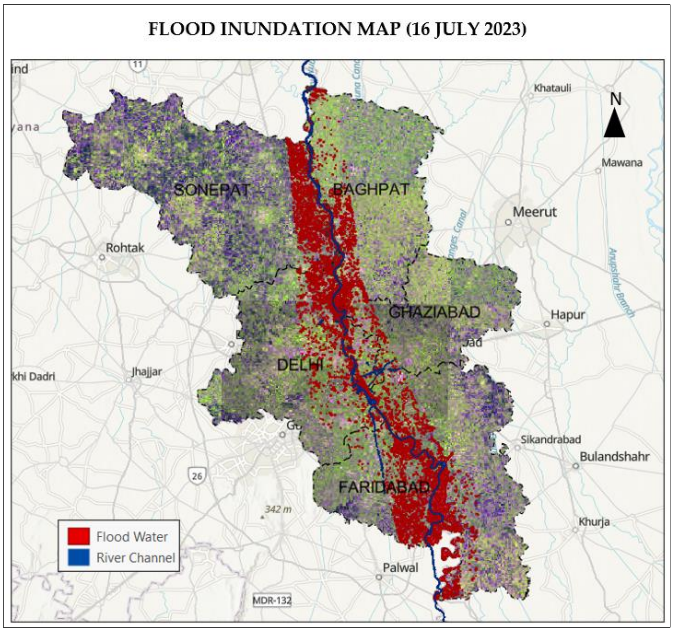


**Fig. 5** Flood Inundation Map for 16 July 2023.

On July 16 the water level of Yamuna river in Delhi recedes to 205.78 meters. The flood inundation mapping was done for 16 July using the same methodology. Pixels in red colour and blue colour represents the pre flood river channel. On 16 July the South East part of the study area were also severely flooded consisting parts of Gautam Budh Nagar and Faridabad.

*Land Use Land Cover Classification:* The LULC map was prepared using classification map was created from Sentinel 2 L2A imagery using Land Cover Classification (Sentinel-2) pretrained model from ArcGIS Living Atlas of the World for May 2023 imagery shown Figure 5. ArcGIS Pro was used for doing the analysis. The study area is classified into Level 1 classification scheme.

The LULC classes are Agricultural areas, Artificial surfaces, Forest and semi natural areas, Water bodies, Wetlands.

*Damage Assessment:* Overlay analysis was done to estimate inundated area per LULC class. Inundated area for all the five classes was calculated and results suggest that Agricultural areas LULC class has highest inundated area for both the days.

With 137.4 sq. km and 190.31 sq. km. area Agricultural land is the topmost flood affected class for both the days. The effects of flood water inundation can be short term such as water logging, crop damage, etc. and can be long term such as loss of nutrients, erosion of top layer of soil, soil salinity and loss of soil productivity. Water logging of agricultural land due to flood also cause economic loss due to crop failure. 20.74 sq. km area of Artificial surfaces class is inundated. The estimation of inundated area of Built-up and Forest can differ due to specular and diffused scattering of radiations respectively.

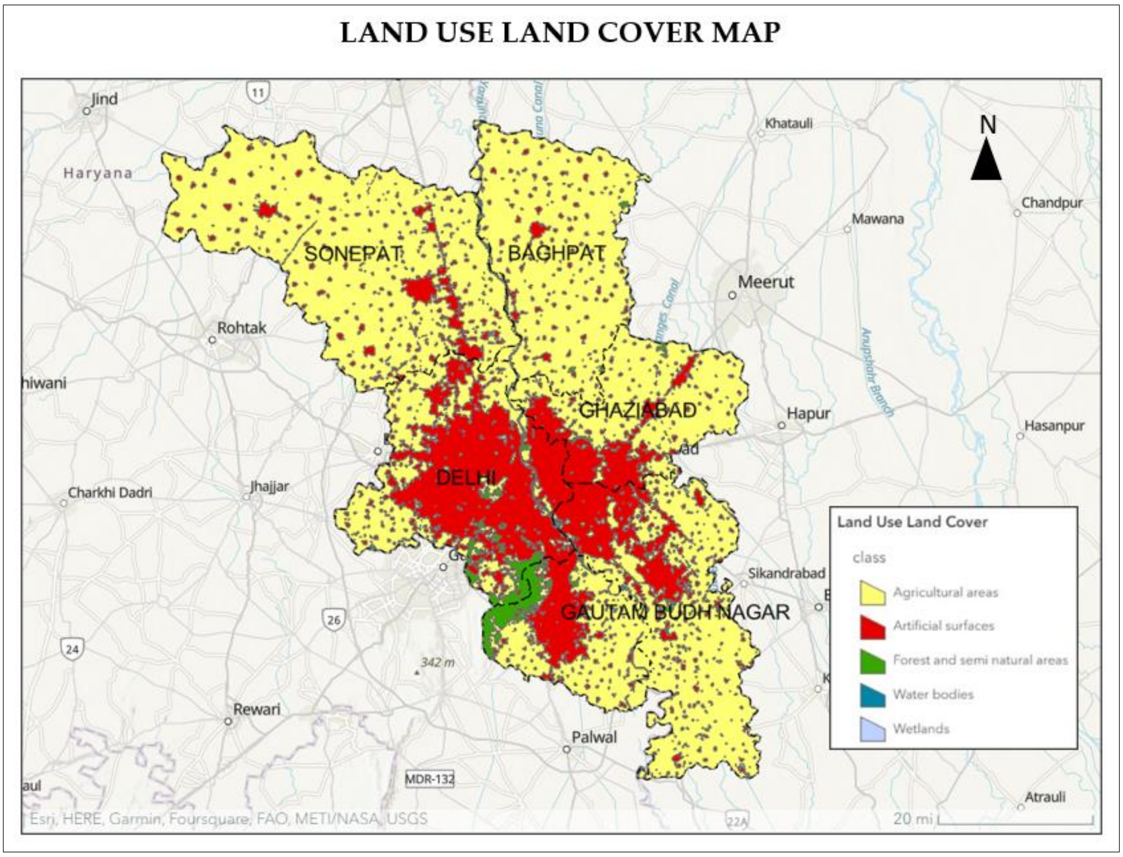


**Fig. 6** Land Use Land Cover Map.

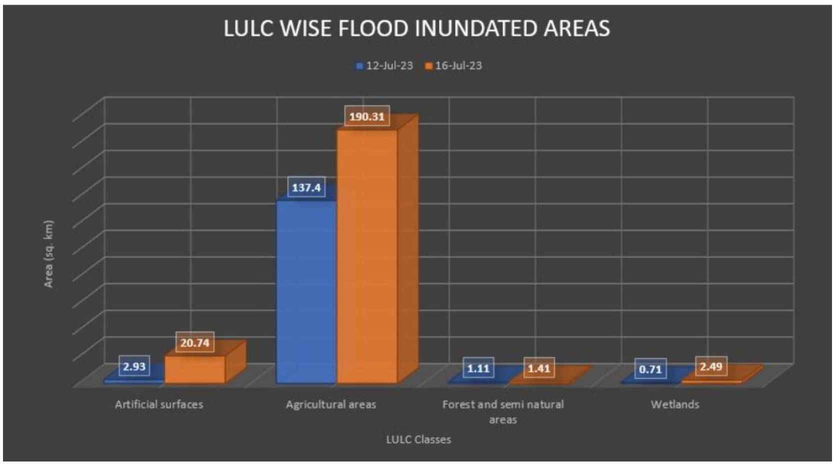


**Fig. 7** LULC wise flood inundated area for 12 July 23 and 16 July 23.

## Conclusions

From results and discussion, using remote sensing and GIS techniques it is possible to identify the flood inundated area and hence flood depth. In this study an overview of the use of SAR for flood mapping is given and experiences using the SAR data along with key processing elements and important analysis techniques that are used for the extraction of flooded area, spread of flood water and duration of flood dynamics. The Sentinel data is very useful for accurately delineating flood inundated area because it allows acquisition of images independent of the cloud cover and its sensor is very much sensitive to response the land or water surface, rough for land and smooth for water. For the dates 12 July and 16 July, the flood extent map has been prepared using single sensor satellite imagery i.e. Sentinel 1 but if we would have adopted the multi sensor approach then flood boundary delineation, duration of flood and hence flood extent could have been analyzed more precisely. Similarly, if we consider long term flood occurred in past, mapping flood inundation and on adding all of them flood hazard map could be generated for the study area.

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## Citation


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