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# Flood Detection using Google Earth Engine: A Comparison of Optical and SAR-based Remote Sensing Methods

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**Abstract:** Floods are one of the most frequent and damaging disasters in India, particularly during the monsoon season. The urban settlement of Mahad, which lies along the Savitri River in Raigad district, Maharashtra, is highly susceptible to flooding. This requires reliable and scalable flood detection methods for disaster preparedness which current methods struggle with concerning issues such as false positives and cloud interference. We compare and contrast five Satellite based flood detection methods implemented in Google Earth Engine (GEE) - hybrid models, NDWI classification, and SAR ratio thresholding. We focus on accuracy, validation strategy, automation, scalability, and type of data (optical/SAR) as our evaluation criteria. The findings shows that NDWI approach are suits for water detection with high precision, but also under-perform in the presence of cloud cover, whereas SAR-based techniques are impervious to cloud cover, but prone to false positives. The effectiveness of ground validation across studies was only limited to one study, which was robust. In relation to these findings, we present a hybrid flood identification approach which incorporates visual validation using FCCs and thresholding with Sentinel-1 SAR VV ratio, as well as NDWI with Sentinel-2. The proposed methodology will enable accurate, cloud-independent and scalable flood mapping in areas affected by monsoon, such as Mahad.

**Keywords**: Flood Detection, Google Earth Engine, Synthetic Aperture Radar, Normalized Difference Water Index

## I. INTRODUCTION

From 1998 to 2015, floods impacted over 2.3 billion people around the world, with a majority living in Asia (Pandey et al., 2022). Floods are one of the most frequent and devastating natural disasters. Climate change has led to more frequent and intense rainfall events, resulting in increased flooding, increased erosion, and the loss of agricultural land (Johary et al. 2023). Therefore, accurate monitoring and flood mapping is fundamentally important for urban planning, food security, and disaster responses globally. Each year, monsoon floods generate an average economic loss greater than USD 7.5 billion, demonstrating how common they are in India (Pandey et al., 2022). Flooding is most common in the monsoon season when India is affected by the significant river systems (Godavari, Brahmaputra, Ganga) overflowing. Flood disasters can have particularly harmful effects to States with rural livelihoods, infrastructure, and agriculture such as, states like Bihar, Assam, Kerala, and Maharashtra. The town of Mahad, located at the confluence of the Gandhari and Savitri Rivers in Raigad district of Maharashtra, receives water from the Western Ghats (Ghogare et al., 2022). Floodwaters can quickly arrive to the city due to the steep setting and proximity to river delivery points. The city, located in a tropical climate, receives annual rainfall and often exceeds 4000 mm (Ghogare et al., 2022). Given the amount of damage to infrastructure, property and the loss of human lives caused by severe floods in 2005, 2016 and 2021 (Ghogare et al., 2022), a scalable and accurate flood detection method is essential for this town and region.

Flood detection has been revolutionized in recent years by remote sensing technologies and cloud-based platforms for spatial and time scale analysis. Satellite imagery, such as Sentinel-1 SAR and Sentinel-2 optical datum, are processed on platforms, such as GEE (Nghia et al., 2022); Sohal et al., 2024). Although optical sensors can use NDWI to identify water bodies (Johary et al., 2023), SAR sensors are also important and advantageous to floods detection as they can observe cloudy or heavy rain conditions (Tiwari et al., 2020). When both sensors are combined with cloud technologies, they represent an effective mechanism for accurate flood mapping (Sohal et al., 2024). While studies have previously undertaken flood detection using SAR and NDWI on their own, both these methods have challenges relating to cloud cover or performance issues with false positives (Tiwari et al., 2020).

While some studies are properly validated and detailed, others rely on non-reproducible manual threshold (Tiwari et al., 2020). The majority of studies that have validated flood maps in chronically flooded areas such as Mahad, in the changing monsoon season, have either not been tested over multiple years or have not used multi-satellite indexes that were combined (Nghia et al., 2022; Tiwari et al., 2020). These examples emphasizing the need for detection methods that are reliable, hybrid, and scalable. This study seeks to evaluate the performance of five different techniques to detect floods derived from satellite data and the Google Earth Engine for the Savitri River Basin area of Mahad. This comparison will help identify the most precise and scalable method for future more detailed long-term monitoring and analysis of floods. The study outlines and gives an overview of current detection techniques for floods, outlines the pros and cons of each, and suggests a hybrid technique which utilizes NDWI filtering and ratios from SAR as a threshold. The hybrid method will be deployed in the future comparative study after it has been validated and performed through satellite imagery

## II. STUDY AREA

### A. Individual Review of 5 Papers

1) A. C. Pandey, K. Kaushik, and B. R. Parida: Google Earth Engine for large-scale flood mapping using SAR data and impact assessment on agriculture and population of Ganga–Brahmaputra Basin (Pandey et al., 2022): The research employed Google Earth Engine to map the extent of coverage of the Ganga-Brahmaputra flood from Sentinel-1 SAR data with VH polarization. The ratio thresholding method was used by dividing the post-flood image by the pre-flood image. Flooding was identified as a threshold value of more than 1.25. Even though the method was scalable and efficient using GEE, ground truthing was not demonstrated in the paper. The method was limited for overwater and vegetation but worked well for cloudy pixels. No optical index was employed in the research to eliminate false positives.

2) B. P. Q. Nghia, I. Pal, N. Chollacoop, and A. Mukhopadhyay: Applying Google Earth Engine for flood mapping and monitoring in the downstream provinces of Mekong River (Nghia et al., 2022): This study investigated six flood-prone provinces in the Mekong Delta of Vietnam. Using Sentinel-1 SAR data (VV polarization), the study processed the images using JavaScript in Google Earth Engine. Similar to Paper 1, they again used SAR ratio thresholding with a threshold value of 1.25. However, the study was able to derive a strong correlation (R2 ≥ 0.7) when it validated its results against hydrological station data from Tan Chau and Chau Doc. This added additional weight to their results. Despite the reliability of the results, the method only relied on SAR data without any optical water index for filtering.

3) R. Johary, C. Révillion, T. Catry, C. Alexandre, P. Mouquet, S. Rakotoniaina, G. Pennober, and S. Rakotondraompiana: Detection of large- scale floods using Google Earth Engine and Google Colab (Johary et al., 2023): The authors used Sentinel-2 optical imagery to calculate the Normalized Difference Water Index (NDWI) for the detection of flood. The authors classified water pixels as NDWI > 0.3. When this methodology was applied in Assam, India, it also showed NDWI was a good way of identifying open water. The only issue was that NDWI was sensitive to atmospheric conditions and cloud cover as it only used optical data. There was no use of thresholding or radar data. Although the technique was simple and easy to use, it was less reliable during times of high monsoon.

4) 2.1.4. R. S. Sohal, M. Madhav, C. Sharma, M. Tikoo, and A. Dhanotra: Flood mapping of Punjab region using Google Earth Engine and remote sensing (Sohal et al., 2024): This research leveraged Google Earth Engine and Sentinel-1 SAR data to investigate the 2018 Kerala flood. The authors classified flooded areas identified by basic ratio thresholding on VV-polarized SAR imagery. The GEE platform allowed for rapid results and cloud-based processing, but the approach was only applied to a single event, and ground truth validation was lacking. The approach was not combined with any water index, nor was it assessed over a number of years. While it seems to have worked as a case study, the scalability of the approach as well as hybridization weren't assessed.

5) 2.1.5. V. Tiwari, V. Kumar, M. A. Matin, A. Thapa, W. L. Ellenburg, N. Gupta, and S. Thapa, Flood inundation mapping – Kerala 2018; Harnessing the power of SAR, automatic threshold detection method and Google Earth Engine (Tiwari et al., 2020): This investigation offered a hybrid process for flood detection, integrating Sentinel-2's NDWI and Sentinel-1's SAR data. To address this concern and limit false positives from SAR, and mask out permanent water bodies, the authors would only apply NDWI > 0.3. While the study highlights the need for automated and scalable methods, it was conducted over a short timeframe without long-term validation. Validation in the real-world and statistical accuracy metrics had not been addressed.

**COMPARISON TABLE:**

| Field | Pandey, Kaushik, and Parida (Pandey et al., 2022) | Nghia, I. Pal, N. Chollacoop, and A. Mukhopadhyay (Nghia et al., 2022) | Johary, Révillion, Catry, Alexandre, Mouquet,Rakotoniaina, Pennober, and Rakotondraompiana (Johary et al., 2023) | Sohal, Madhav, Sharma, Tikoo, and Dhanotra (Sohal et al., 2024) | Tiwari, Kumar, Matin, Thapa, Ellenburg, Gupta, and Thapa. (Tiwari et al., 2020) |
|---|---|---|---|---|---|
| Title | Flood-mapping SAR GEE | GEE Flood Mapping – Mekong (2022) | Flood Inundation Mapping using Sentinel-1 & GEE | Flood Mapping of Punjab Region Using GEE | Flood Mapping Using GEE: Kerala 2018 |
| Year | 2022 | 2022 | 2021 | 2024 | 2020 |
| Study Location | Ganga-Brahmaputra Basin(Bihar, Assam, WB) | Mekong Delta, Vietnam | Madagascar | Punjab, India | Kerala, India |
| Disaster Type | Flood | Seasonal river floods + tidal influence | Flood (Cyclone Batsirai) | Flood | Flood (2018 Kerala) |
| Data Time Period | July–Aug 2020 | 2015–2020 (main), 2017–2020(validation) | Feb 2022 | July 2020 | July–August 2018 |
| Satellite Sensor(s) | Sentinel-1 (VH), Landsat-8 (for validation) | Sentinel-1 SAR (VV) | Sentinel-1 (VH) | Sentinel-1, Sentinel-2 | Sentinel-1, Sentinel-2 |
| Sensor Type | SAR + Optical | SAR | SAR | SAR + Optical | SAR + Optical |
| Platform/Tools | GEE, ArcGIS | GEE, JavaScript, QGIS | GEE | GEE | GEE |
| Algorithms/ Methods | SAR Ratio Change Detection (VH), Threshold = 1.25 | Change Detection + Thresholding (1.25) | VH Ratio + Terrain Mask + Filtering | VH Thresholding, NDWI, Classification | VH Thresholding, NDWI, Binarization |
| Flood Mapping Approach | Change Detection + Ratio + Threshold | Change Detection | VH Ratio-Based Detection | Combined SAR + NDWI Classification | NDWI + VH-Based Classification |
| Resolution | 10m (SAR), 30m (Landsat) | 20m spatial, 12-day temporal | 10m | 10m | 10m |
| Accuracy Assessment | Visual Validation (Landsat FCC) | $R^2 = 0.79–0.94$ | Visual Comparison | Google Earth Basemap Validation | Google Earth & News Map Validation |
| Ground Truth / Validation | Landsat-8 visual check | Water level correlation | Not provided | Visual check with imagery | Visual + News Maps |
| Strengths / Highlights | Large-scale, fast, cloud-resistant, SAR + GEE | Multi-year, high $R^2$, fast | Automated, scalable | Dual sensor improves accuracy | Cloud-resistant, clear mapping |
| Limitations / Challenges | No numerical accuracy | Lacks pre-2014 data | Radar distortion, no stats | Focused on one event | Limited validation, no score |
| Result Quality | High (visual) | High (validated) | High (visually confirmed) | Reliable & clear | Visually accurate |
| Applications Suggested | Flood assessment, policy planning | Flood Management & planning | Emergency planning | Risk assessment | Disaster response |
| Key Insight | SAR + GEE are reliable for large areas | Flood shifting trends | Simple & repeatable VH-based method | SAR + Optical better in monsoon | NDWI + VH give reliable results |
| Our Rating | 5/5 | 4.5/5 | 4.6/5 | 4.3/5 | 4.4/5 |
| Why Suitable? | Works in cloudy monsoon, repeatable | Adaptable to Indian rivers | Scalable, cloud-free | Good for Indian conditions | Robust with open tools & data |

**Table 1:** Comparative of various research papers

### B. Comparative Summary:

There were four flood detection methods employed among the five studies reviewed, namely SAR nominal ratio thresholding, NDWI water masking, and two-part hybrid methodologies that combine both SAR nominal-based thresholds together with NDWI water masking.

While all SAR-based methodologies are cloud independent and successful during the monsoon season, they often resulted in most false positives. NDWI based methods often resulted in good water identification, but were not as effective during cloudy periods. The other papers failed to conduct field-based plausible accuracy verification or validation, other than Paper 2 (Nghia et al., 2022), which had acceptable ground validation using hydrological data. Furthermore, no study that was reviewed combined SAR and NDWI methods with automation and ground truth validation across multiple years. These findings informed our hybrid approach, and we recommend the following best components to conduct an accurate, scalable, long-term flood detection study in the Mahad region: NDWI-based water masking, SAR nominal ratio methodology based on VV polarization, and visual photo validation. The rationale for the hybrid methodology steps and structure will be presented in the next section.

## III. METHODOLOGY

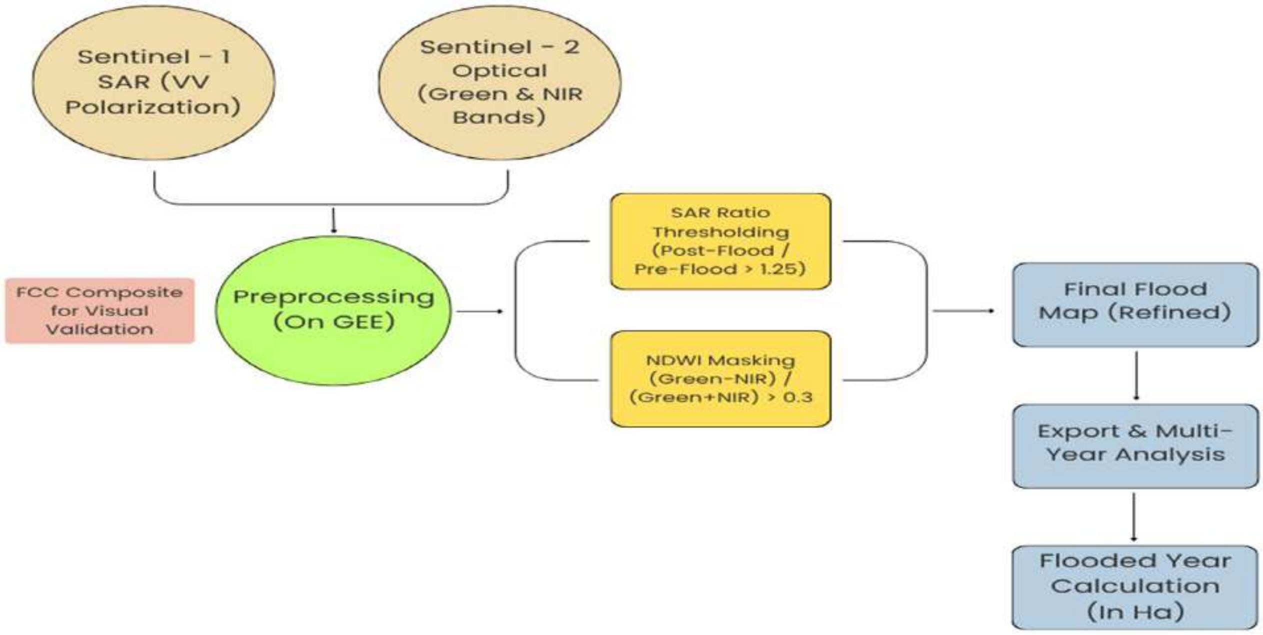


**Image 1:** Flowchart of Methodology

### A. Literature Based Data Collection:

A comparative research design utilizing the literature will be utilized in this study. Based on their utilization of flood detection methodologies employing satellite data in flood-prone areas using Google Earth Engine (GEE), a total of five peer-reviewed research articles were selected. The articles were selected from credible journals and each article utilized a different specific methodology; such as NDWI-based water mapping, SAR ratio thresholding, or combined methodologies. Additionally, to better understand the flood dynamics of the study area, one additional local case study specific to Mahad was examined. The introduction, methods, results, and limitations for each paper were completely read

### B. Comparison Criteria:

The selected papers were compared using several evaluation criteria, including:

- Type of satellite data used (SAR, Optical)
- Method of flood detection (Ratio, NDWI, Difference)
- Validation method (if any)
- Tool/platform used (GEE, QGIS, Java, Python)
- Scalability and cloud resistance
- Accuracy, automation potential, and limitations These criteria were organized in a comparative table (Table 1) and used to identify gaps and strengths in each method.

### C. Evaluation and Method Selection:

The comparative analysis showed Paper 5 (Tiwari et al., 2020) was the only one to add NDWI masking for reducing false positives, while Paper 2 (Nghia et al., 2022) used the best validation with hydrological data. Papers 1 and 4 were effective, but neither used any water filtering and had validation. Paper 3 (Johary et al., 2023) was affected by cloud cover, only using NDWI. None of the studies combine visual validation with a combination of SAR and NDWI, therefore a hybrid strategy that took the best of these papers was selected.

### D. Proposed Hybrid Method (Overview Only):

The defined hybrid methodology encompasses these elements:

1. SAR Ratio Thresholding using Sentinel-1 (Nghia et al., 2022)
2. NDWI filtering using Sentinel-2 for false positive removal (Tiwari et al., 2020)
3. Visual validation through FCC imagery (Pandey et al., 2022)

This method has been developed specifically to be used under cloudy monsoonal conditions and reduce the occurrence of misclassification while allowing for a scalable multi-year analysis. A detailed implementation of this methodology will be the focus of our subsequent research paper.

### E. Tools and Platforms Studied:

Each of these methods was assessed in the context of Google Earth Engine (GEE), a useful platform that supports large geospatial datasets with cloud-based processing. All studies used similar tool sets which included using Sentinel-1 SAR, Sentinel-2 optical bands, NDWI index, SAR ratio logic, Java.

## IV. DISCUSSION SECTION

### A. Justification Of the Hybrid Method:

The proposed hybrid method was developed by carefully considering the strengths and weaknesses of five earlier flood detection studies using satellite-based remote sensing. For example, thresholding the advantage of using VV polarization SAR ratios was justified by its strong relationship with hydrological station data ($R2 \geq 0.7$) which we borrowed from (Nghia et al., 2022). SAR by itself, however, typically mistakes low-lying terrain or settled areas for water; producing false positives. This is why we included NDWI filtering from (Tiwari et al., 2020) to mask non flooded permanent water bodies and reduce these misclassifications. Finally, in order to eliminate misunderstanding of flood extents we also incorporated visual validation using FCC images from (Pandey et al., 2022) to manually check flood extents in confused urban-river junctions like Mahad

| Step in Hybrid Method | Taken From | Why Taken |
|---|---|---|
| SAR Ratio Thresholding (VV, >1.25) | Paper 2 (Nghia et al., 2022) | Strong statistical validation with hydrology data |
| NDWI Filtering (NDWI > 0.3) | Paper 5 (Tiwari et al., 2020) | Removes false positives from SAR |
| FCC-Based Visual Validation | Paper 1 (Pandey et al., 2022) | Manual confirmation of results in urban/flood zones |

**Table 2:** Steps in Hybrid Flood Mapping Method with Source and Justification

### B. Advantages Over Existing Methods:

The hybrid method has several advantages over traditional single-sensor methodologies. Theoretical applications of SAR-only methods, like the works of (Sohal et al., 2024) and (Pandey et al., 2022), have superior cloud penetration but lack a mechanism of ground validation and any filtering capability, which often results in excessive detection or over-detection. On the other hand, optical-only methods, like that of (Johary et al., 2023), rely on bright clear skies and, because of heavy cloud coverage in the monsoon season, have a poorly architecture. The hybrid method offers a more accurate and neutral flood detection process appropriate to Mahad by combining SAR's cloud independent duty, the NDWI's water masking, and the effort of manual validation.

### C. Applicability to the Mahad Region:

Due to its local topography, river junction, and heavy monsoon precipitation, Mahad is a flooding-prone area. Furthermore, flood mapping is challenged by the hilly slopes, vegetation, and urban development in the local terrain. A hybrid approach is particularly appropriate for Mahad because it can manage the region's persistent cloud cover by leveraging SAR data. Furthermore, NDWI filtering helps distinguish floodwaters from urban and vegetated regions, while manual FCC assessment can resolve uncertain cases where the river and urban areas meet. These features ensure the hybrid approach is robust in analyzing flooding during monsoon periods and examining the Savitri River basin across several years for an accurate assessment of flooding over the longer term.

### D. Limitations of the Approach:

Despite the aforementioned progress, using a hybrid approach has some limitations. First, because Mahad does not have local ground-based hydrological data, validation was achieved only using satellite-sequence imagery. Second, like the exhaustive comparison approach, it relied on an expert to determine four satellite and two NDWI threshold levels, and therefore reliance on an expert is an assumption that could be subjective. Reliability and repeatability may be enhanced by fully automating the process and using dynamic thresholding or machine learning

### E. Future Scope:

This study establishes a conceptual and comparative foundation for future research in which Google Earth Engine will use the hybrid approach over ten years [Paper 2 (Nghia et al., 2022)]. The goals are to create multi-year flood maps, validate flood extents using FCC imagery, and investigate seasonal trends in flooding. The approach can be used for research and to realize applications such as disaster management, urban planning, flood early warning systems, and resilience planning to meet SDG targets in Mahad and other towns with monsoon flooding challenges.

## V. CONCLUSION

In light of their applicability in flood-prone zones like Mahad, this study presented a comprehensive comparison of five satellite-based flood detection methods using the Google Earth Engine (GEE). The paper has shown that SAR-based methods serve as a cloud-free monitoring option but often present false positives as an issue. Meanwhile, the optical methods, which are sensitive to cloud cover, have better capability for water body discrimination such as NDWI. Other studies often lack validation or noise filtering, and very few used hydrological validation. The outcomes from this study indicate a hybrid method using Sentinel-2 images for visual validation and NDWI filtering and ratio thresholding SAR (VV polarization) method.The proposed hybrid method aims to achieve high accuracy, scaling potential, and cloud inundated areas affected by the monsoon season. The hybrid method also has strong potential to navigate the landscape, climate, and hydrology of the Savitri River basin while addressing inherent weaknesses or limitations for existing methods. In its second stage, this study will apply the methodology outlined before and create and analyze multi-year composite flood maps of the Mahad area using actual satellite data on the GEE platform

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## REFERENCES

1. S. S. Ghogare, S. B. Ghangale, P. S. Borhade, and A. V. Dawkhar, "Case study of Mahad flood," Int. J. Res. Appl. Sci. Eng. Technol. (IJRASET), vol. 10, no. 4, pp. 2017–2020, 2022. https://doi:/10.22214/ijraset.2022.42080.
2. R. Johary, C. Révillion, T. Catry, C. Alexandre, P. Mouquet, S. Rakotoniaina, G. Pennober, and S. Rakotondraompiana, "Detection of large-scale floods using Google Earth Engine and Google Colab," Remote Sens., vol. 15, no. 22, p. 5368, 2023. https://doi:/10.3390/rs15225368.
3. B. P. Q. Nghia, I. Pal, N. Chollacoop, and A. Mukhopadhyay, "Applying Google Earth Engine for flood mapping and monitoring in the downstream provinces of Mekong River," Prog. Disaster Sci., vol. 14, p. 100235, 2022. https://doi:/10.1016/j.pdisas.2022.100235.
4. A. C. Pandey, K. Kaushik, and B. R. Parida, "Google Earth Engine for large-scale flood mapping using SAR data and impact assessment on agriculture and population of Ganga–Brahmaputra Basin," Sustainability, vol. 14, no. 7, p. 4210, 2022. https://doi:/10.3390/su14074210.
5. R. S. Sohal, M. Madhav, C. Sharma, M. Tikoo, and A. Dhanotra, "Flood mapping of Punjab region using Google Earth Engine and remote sensing," Proc. Int. J. Sci. Technol., vol. 1, no. 4, pp. 12–19, 2024. https://doi:10.62796/pijst.2024v1i402.
6. V. Tiwari, V. Kumar, M. A. Matin, A. Thapa, W. L. Ellenburg, N. Gupta, and S. Thapa, "Flood inundation mapping – Kerala 2018; Harnessing the power of SAR, automatic threshold detection method and Google Earth Engine," PLoS One, vol. 15, no. 8, e0237324, 2020. https://doi:/10.1371/journal.pone.0237324.