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# Flood Mapping of Punjab Region Using Google Earth Engine and Remote Sensing

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**Abstract**- This study harnesses the capabilities of Google Earth Engine (GEE) and Sentinel-1 Synthetic Aperture Radar (SAR) data to detect and monitor floods in the Punjab region of India. Leveraging the change detection mechanism and advanced processing techniques, the research aims to provide accurate and timely flood maps crucial for disaster management and mitigation strategies. By integrating multi-temporal SAR data with other satellite imagery, the study seeks to enhance flood detection accuracy and comprehensiveness. The outcomes of this research contribute to the advancement of remote sensing-based flood monitoring and support effective decision-making in disaster-prone regions.

## Introduction-

Floods are among the most devastating natural disasters, causing significant socio-economic impacts, property damage, and loss of life. Accurate and timely flood monitoring and mapping are crucial for disaster management, mitigation strategies, and emergency response. Remote sensing has become an invaluable tool in flood monitoring due to its ability to provide large-scale, real-time data across various environmental conditions. Among the various platforms available, Google Earth Engine (GEE) stands out as a powerful cloud-based geospatial analysis platform that facilitates the visualization and analysis of satellite imagery at planetary scale (Gorelick et al., 2017). GEE leverages extensive datasets from numerous satellites, enabling detailed environmental monitoring and change detection. Specifically, Synthetic Aperture Radar (SAR) data from satellites such as Sentinel-

1 is highly effective for flood monitoring due to its ability to penetrate cloud cover and provide high-resolution imagery regardless of weather conditions (Singh et al., 2020; Pham-Duc et al., 2017). Sentinel-1 SAR data, with its Ground Range Detected (GRD) products, offers precise and reliable flood detection capabilities, crucial for accurate disaster assessment.

The Punjab region of India, with its densely populated areas and agricultural landscapes, is particularly vulnerable to the impacts of flooding. Timely and accurate monitoring of flood events is essential for effective disaster management and mitigation efforts in the region. Remote sensing technologies have revolutionized flood monitoring by providing a wealth of spatial and temporal information from satellite observations. Among these technologies, Google Earth Engine (GEE) has emerged as a powerful platform for geospatial analysis, offering access to a diverse array of satellite imagery and datasets. Sentinel-1 Synthetic Aperture Radar (SAR) data, available through GEE, has proven to be invaluable for flood detection and monitoring. Unlike optical imagery, SAR data can penetrate cloud cover and capture images regardless of weather conditions, making it particularly well-suited for flood mapping in regions prone to frequent cloud cover, such as the Punjab. By leveraging multi-temporal SAR data and advanced processing techniques, researchers can detect changes in surface water extent and identify flood-affected areas with high accuracy and precision. In addition to SAR data, the integration of other satellite datasets, such as Landsat imagery, enhances the capability of flood monitoring by providing complementary information on land cover, vegetation, and terrain characteristics. Furthermore, the application of machine learning algorithms to remote sensing data allows for automated flood detection and classification, improving the efficiency and reliability of flood monitoring efforts.

In light of these advancements, this study aims to harness the capabilities of GEE and Sentinel-1 SAR data for flood detection and monitoring in the Punjab region of India. By employing state-of-the-art change detection techniques and advanced processing algorithms, the research seeks to generate timely and accurate flood maps that can support decision-making processes related to disaster preparedness, response, and recovery. Ultimately, the outcomes of this study hold the potential to enhance the resilience of communities in flood-prone areas and mitigate the adverse impacts of flooding on both human populations and the environment.

## Relate works-

Several studies have demonstrated the utility of Sentinel-1 SAR data for flood detection. Brakenridge et al. (2003) and Twele et al. (2016) highlight the advantages of SAR for automated flood mapping, emphasizing its ability to provide accurate assessments even under adverse weather conditions. Clement et al. (2018) and Zhao et al. (2019) further illustrate the use of multi-temporal SAR data for effective flood monitoring, employing change detection mechanisms to identify inundated areas. In addition to SAR data, integrating multi-source data from other satellites such as Landsat enhances the comprehensiveness of flood analysis. For instance, Khan et al. (2011) combined satellite remote sensing with hydrologic modeling to map flood inundation in the Lake Victoria Basin, demonstrating the synergistic potential of multi-source data integration. Liu et al. (2021) introduced novel thresholding methods for SAR-based flood detection, enhancing the precision of flood extent mapping. Machine learning approaches have also been incorporated into flood mapping, leveraging the capabilities of remote sensing data to improve detection accuracy. Zhang et al. (2019) applied machine learning algorithms to multi-source remote sensing data for flood mapping, highlighting the potential of artificial intelligence in enhancing remote sensing applications. Similarly, Fu et al. (2017) utilized machine learning for urban flood detection with SAR data, underscoring the benefits of advanced computational techniques in environmental monitoring.

Another crucial aspect of flood monitoring is the long-term observation of surface water changes. Pekel et al. (2016) provided high-resolution global surface water mapping, which is essential for understanding long-term changes in water distribution. Manfreda et al. (2018) applied the Normalized Difference Vegetation Index (NDVI) for urban flood detection, showcasing the utility of vegetation indices in flood studies. Integrating multiple datasets and advanced processing techniques within platforms like GEE allows for comprehensive flood analysis. Teng et al. (2020) monitored flood evolution using Sentinel-1 SAR and Landsat data in GEE, exemplifying the benefits of multi-source data integration. Grimaldi et al. (2016) discussed the use of remote sensing-derived water extent to constrain hydraulic models, identifying both opportunities and challenges in the application of remote sensing for flood forecasting.

Moreover, Long et al. (2014) utilized dual-polarized SAR for flood mapping on GEE, while Sun et al. (2019) implemented deep learning for change detection in multi-source remote sensing data. These advancements underscore the evolving landscape of remote sensing technologies and methodologies. Finally, accurate flood monitoring requires consideration of permanent water bodies to distinguish between regular water presence and flood-induced inundation. Di Baldassarre et al. (2009) and Martinis and Twele (2010) emphasized the importance of calibrating hydraulic models and automated flood services using satellite data, ensuring precise flood assessment. This study aims to utilize the capabilities of GEE and Sentinel-1 SAR data for flood detection in the Punjab region of India. By employing change detection mechanisms and advanced processing techniques, the study seeks to provide accurate and timely flood maps, contributing to better disaster management and mitigation strategies.

Recent advancements in geospatial analysis and remote sensing have enabled detailed environmental monitoring, particularly through platforms like Google Earth Engine (GEE). Gorelick et al. (2017) highlight the planetary-scale capabilities of GEE for analyzing satellite imagery. Studies such as Singh et al. (2020) and Pham-Duc et al. (2017) demonstrate the effectiveness of Sentinel-1 SAR data for flood detection, leveraging its resilience to environmental factors like cloud cover, which commonly affect optical imagery. Brakenridge et al. (2003) and Twele et al. (2016) discuss automated flood mapping using SAR data, emphasizing the advantages of radar in providing accurate flood assessments. Clement et al. (2018) and Zhao et al. (2019) further explore multi-temporal SAR data for flood monitoring, utilizing change detection mechanisms to identify inundated areas. Khan et al. (2011) integrate satellite remote sensing with hydrologic modeling for flood mapping in the Lake Victoria Basin, while Liu et al. (2021) introduce a novel thresholding method for SAR-based flood detection. Machine learning approaches for flood mapping, as presented by Zhang et al. (2019), enhance the precision of remote sensing applications.

Pekel et al. (2016) provide high-resolution global surface water mapping, which is crucial for understanding long-term changes in water distribution. Manfreda et al. (2018) apply NDVI for urban flood detection, showcasing the utility of vegetation indices in flood studies. Teng et al. (2020) monitor flood evolution using Sentinel-1 SAR and Landsat data in GEE, exemplifying the integration of multi-source data for comprehensive flood analysis. Grimaldi et al. (2016) discuss the use of remote sensing-derived water extent to constrain hydraulic models, identifying both opportunities and challenges. Long et al. (2014) utilize dual-polarized SAR for flood mapping on GEE, and Sun et al. (2019) implement deep learning for change detection in multi-source remote sensing data. Fu et al. (2017) employ machine learning algorithms for urban flood detection with SAR data, highlighting the potential of artificial intelligence in enhancing remote sensing applications. Di Baldassarre et al. (2009) present a technique for calibrating hydraulic models using uncertain satellite data, while Martinis and Twele (2010) introduce an automated flood service using TerraSAR-X. These studies collectively illustrate the diverse methodologies and applications of remote sensing and GEE in environmental monitoring, particularly for flood detection and assessment. They provide a robust foundation for understanding the capabilities and limitations of current technologies in addressing environmental challenges.

## Methodology-

This study leverages Google Earth Engine (GEE) to analyze Sentinel-1 SAR GRD data for flood detection in Punjab, India. The radar-based dataset, unaffected by environmental factors like mist and cloud cover, enhances accuracy and precision over optical imagery. Using a Change Detection mechanism, the study compares images from before and after a flood event to identify changes. The methodology begins with data pre-processing, importing Punjab's shapefile as a Feature Collection and selecting the 'IW' mode for image acquisition, suitable for land and coastal areas. The VH polarization band is chosen for its effectiveness in detecting water and flooded pixels, as water does not reflect light in this band, appearing dark. Additional selections of meta attributes like resolution and orbit properties complete the pre-processing.

Next, temporal filters are applied to select data for the specified periods, and a mosaic reducer condenses the image collections into single composite images. These images are clipped to the region of interest but initially contain Speckle Noise, which is removed using Speckle Filtering. This process involves converting images to natural log units, applying the Standard function for Speckle filtering, and converting back to dB units for visualization. Change detection is performed by dividing the post-flood image by the pre-flood image and applying a threshold to isolate flooded pixels, which are represented as '1' in the masked image, while unflooded pixels are '0'. The district-wise flooded area is calculated by summing the pixel areas within each district, and the results are exported as CSV files. The flood-detected image is exported as a GeoTIFF file for further processing in QGIS to create the study area map. To refine accuracy, the study calculates the permanent water area for each district using the 'JRC Global Surface Water Mapping Layers, v1.4' dataset. This dataset maps surface water distribution from 1984 to 2021, with the ‘seasonality’ band indicating the number of months water is present at a location. Applying a threshold to this band, the permanent water pixels are identified and clipped to the Punjab region. The district-wise permanent water area is subtracted from the initial flooded area to determine the net flooded area. The final data is exported as CSV files, and images are processed in QGIS to generate the study area map. This methodology provides a robust framework for accurate flood detection and area calculation, aiding in disaster management and resource allocation.

## Results-

The attached figure presents a detailed spatial representation of flood-affected areas in the state of Punjab, India. The map delineates the boundaries of Punjab’s districts and highlights regions impacted by flooding. The inset map in the top left corner situates Punjab within the broader context of India, with Punjab highlighted for reference. This provides an understanding of the state’s location relative to the entire country. The map distinctly marks flooded areas in a darker shade (possibly red or similar), clearly distinguishing them from unflooded regions which are shown in a lighter shade. This visual contrast facilitates an immediate assessment of the extent and distribution of flooding across Punjab. Each district within Punjab is outlined and labeled, enabling precise identification of the areas affected by flooding. District names such as Amritsar, Ludhiana, Patiala, and others are indicated on the map. The scale bar at the bottom of the map provides a reference for distance, with markers at 0, 25, 50, 75, and 100 kilometers, helping to gauge the spatial extent of the flooded areas. A north arrow in the top right corner ensures proper orientation of the map, aiding in spatial analysis and interpretation. The legend, located at the bottom left of the map, explains the color coding used to differentiate between flooded and unflooded areas. This legend is crucial for interpreting the map accurately.

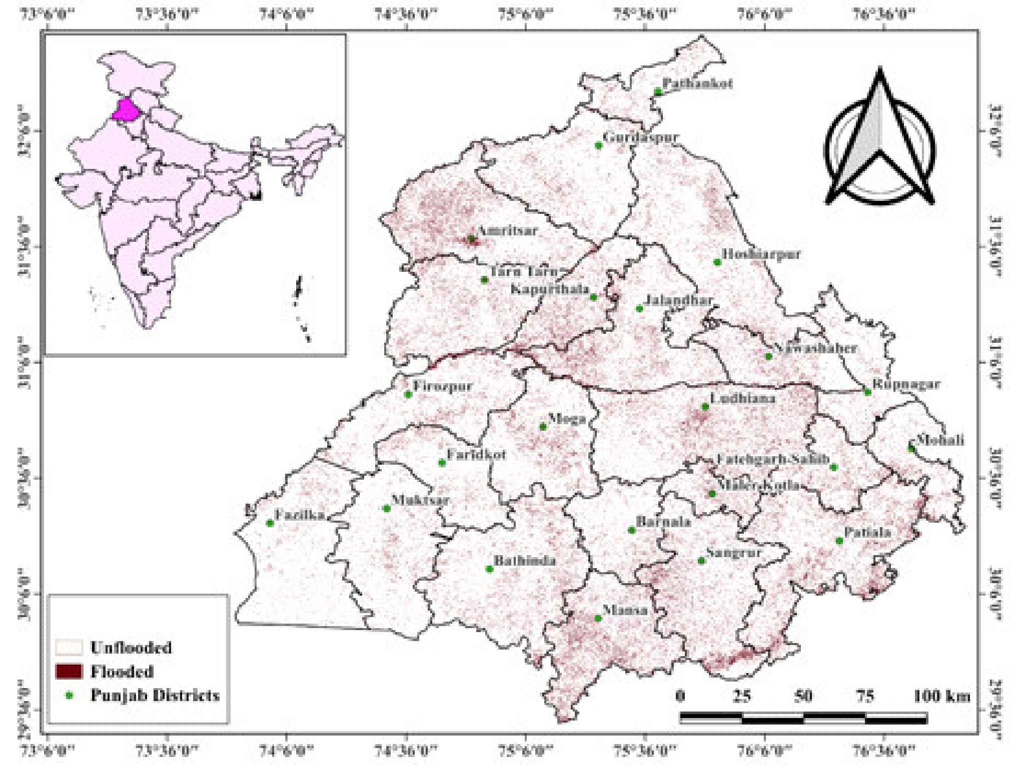

**Figure 1 Results showing flooded regions of Punjab in July 2023**

## Conclusions-

From the figure, it is evident that the flooding is widespread, affecting numerous districts across Punjab. Districts such as Ludhiana, Patiala, and others show significant areas marked as flooded. The spatial distribution of the flooding appears uneven, with some districts experiencing more extensive flooding than others. Major cities and towns within Punjab, indicated by green dots, provide context regarding the impact of flooding on populated areas and infrastructure. For instance, cities like Ludhiana and Patiala, which are major urban centers, are located in or near flooded regions, suggesting potential significant impacts on population and infrastructure. The figure underscores the severity and geographical spread of flooding in Punjab, highlighting the necessity for targeted disaster management and relief efforts in the affected districts. The clear demarcation of flooded areas aids in identifying regions that require immediate attention and resources for flood mitigation and recovery. Additionally, the proximity of major cities to flooded areas suggests potential economic and infrastructural impacts, necessitating a coordinated response to minimize disruption and support affected communities. Overall, the detailed spatial representation provided by the figure serves as a critical tool for policymakers, emergency responders, and researchers in understanding and addressing the challenges posed by flooding in Punjab. The map's clarity and detail facilitate informed decision-making and strategic planning to enhance flood resilience and response efforts in the region.

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