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Monitoring and assessing the damage caused by floods and forecasting their risk in the future.

INTRODUCTION:

KERALA FLOODS 2018
(https://thepolicytimes.com/the-floods-94-years-later-modern-day-keralas-worst-nightmare/)

Floods are one of the most devastating natural disasters that have affected millions of people worldwide. They occur when water overflows from its natural channels, such as rivers, lakes, or oceans, and inundates the surrounding areas. Floods can have severe ecological, social, and economic impacts, causing loss of life, displacement of people, damage to infrastructure, and disruption of livelihoods. Tragically, floods have been responsible for some of the worst disasters in history, both worldwide and in India.

In India, floods are a recurring phenomenon, affecting millions of people every year. The country's diverse geography and climate make it vulnerable to floods caused by monsoon rains, cyclones, and cloudbursts. Some of the worst flood events in India include the 2018 Kerala floods, which caused over 400 deaths and displaced over a million people, and the 2019 Maharashtra floods, which claimed over 50 lives and caused widespread damage to property and infrastructure. The country's worst flood disaster, however, dates back to 1971 when the River Kosi in Bihar breached its embankment, causing massive floods that killed over 10,000 people and displaced millions.

Globally, floods have also caused significant devastation and loss of life. The 1931 China floods are considered the deadliest flood event in history, with an estimated death toll of around 4 million people. In more recent times, the 2004 Indian Ocean tsunami caused by an earthquake off the coast of Sumatra resulted in widespread flooding and claimed over 230,000 lives across several countries, including Indonesia, Sri Lanka, and India.
In this context, it is clear that floods pose a significant threat to human life and the environment. It is essential to understand the causes and effects of floods and develop effective strategies to mitigate their impact.

GOAL:

The goal is to study the Kerala floods of 2018 in order to gain insights into effective flood monitoring and prediction techniques. By analyzing the Sentinel-1 dataset and applying various image processing techniques, we aim to create flood maps and anticipate when floods are likely to occur. Additionally, we aim to develop a tool that can aid in disaster response efforts and risk mitigation, thereby reducing the impact of flooding on property and human life.

Through the study of the Kerala floods of 2018, we hope to learn how to effectively utilize the Sentinel-1 dataset and other relevant technologies to monitor and predict floods. By analyzing the data and mapping the extent of flooding, we can gain insights into how to better respond to future flood events. Additionally, we hope to learn how to effectively communicate flood risk information to those who may be affected, in order to minimize the impact of future floods on human life.

Ultimately, the goal of learning from the Kerala floods of 2018 is to develop effective flood monitoring and prediction techniques that can help reduce the risk of property damage and loss of life. By studying the event and applying the lessons learned, we can develop more effective strategies for preventing and mitigating the impact of floods in the future.

ABOUT DATA:

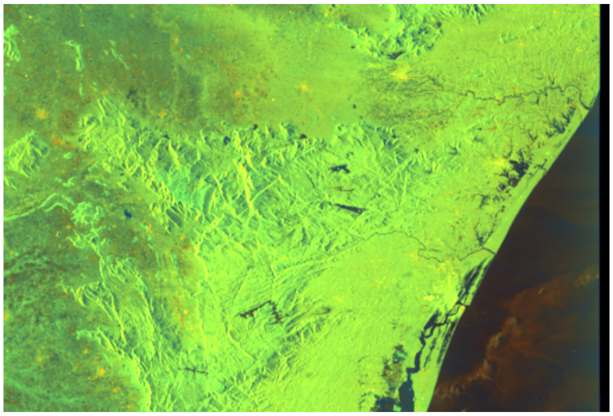
Property	Details
Sensor	C-band Synthetic Aperture Radar (SAR)
Platform	Sentinel-1A and Sentinel-1B
Orbit	Sun-synchronous orbit (14 orbits per day)
Polarization	Dual-polarization (HH+HV or VV+VH)
Swath width	80 km
Resolution	5 m x 20 m (single look), 10 m x 20 m (dual look)
Frequency	5.405 GHz
Acquisition mode	Interferometric Wide (IW), Extra Wide (EW), and Stripmap (SM)
Image format	GeoTIFF

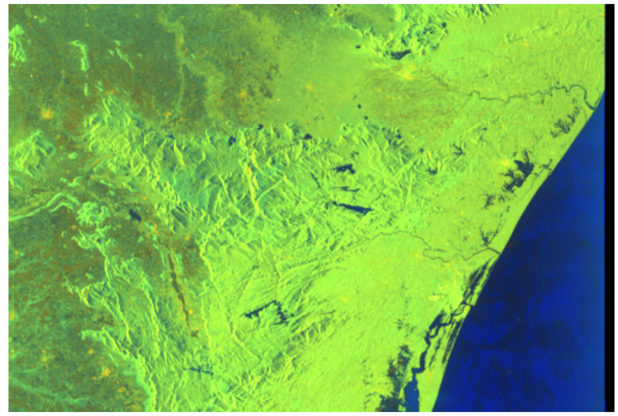
Data size	Varies based on acquisition mode and region, typically several GB per image
Availability	Free and open access through the Copernicus Open Access Hub
Data coverage	Global
Revisit time	6 days

The above table provides an overview of the main properties of the Sentinel-1 GRD (Ground Range Detected) data set. Here's what each column represents:

- **Sensor**: This column specifies that the Sentinel-1 GRD data set is obtained using a C-band Synthetic Aperture Radar (SAR).
- **Platform**: This column specifies the two satellites that acquire the Sentinel-1 GRD data: Sentinel-1A and Sentinel-1B.
- **Orbit**: This column specifies that the Sentinel-1 satellites are in a sun-synchronous orbit, which means that they pass over any given point on the Earth's surface at approximately the same local time each day.
- **Polarization**: This column specifies that the Sentinel-1 GRD data is dual-polarized, meaning that it includes two different polarization modes (HH+HV or VV+VH).
- **Swath width**: This column specifies the width of the area that is imaged by the Sentinel-1 GRD data in a single pass, which is 80 km.
- **Resolution**: This column specifies the spatial resolution of the Sentinel-1 GRD data, which varies based on the look angle and polarization mode, but typically ranges from 5 m x 20 m (single look) to 10 m x 20 m (dual look).
- **Frequency**: This column specifies the frequency of the radar signal used by the Sentinel-1 GRD data, which is 5.405 GHz.
- **Acquisition mode**: This column specifies the three main acquisition modes of the Sentinel-1 GRD data: Interferometric Wide (IW), Extra Wide (EW), and Stripmap (SM).
- **Image format**: This column specifies that the Sentinel-1 GRD data is available in the GeoTIFF format, which is a widely used file format for geospatial data.
- **Data size**: This column specifies that the size of each Sentinel-1 GRD image can vary based on the acquisition mode and region imaged, but typically ranges in size from several gigabytes to tens of gigabytes.
- **Availability**: This column specifies that the Sentinel-1 GRD data is freely available through the Copernicus Open Access Hub.
- **Data coverage**: This column specifies that the Sentinel-1 GRD data provides global coverage of the Earth's surface.
- **Revisit time**: This column specifies that the Sentinel-1 satellites have a revisit time of 6 days, meaning that they pass over any given point on the Earth's surface approximately once every 6 days.

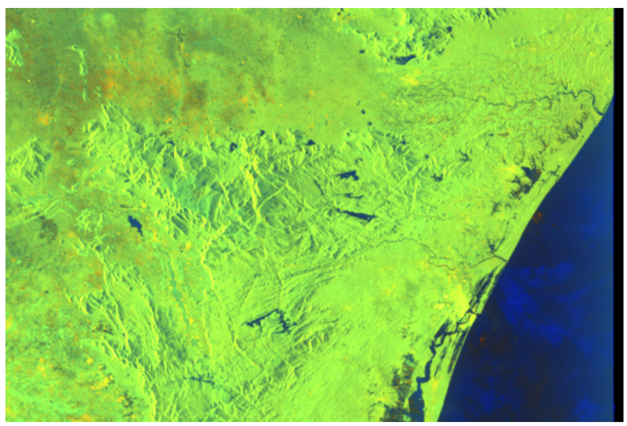
Fig 1.





Before Floods (2018-06-10)

During Floods (2018-07-28)



After Floods (2018-10-20)

Fig 1. (a),(b) & (c) are small image previews of the actual radar data that is contained in the data product. They typically show a grayscale image of the data in the data product, with dark areas representing low radar reflectivity (e.g., areas with little or no scattering of the radar signal) and bright areas representing high radar reflectivity (e.g., areas with strong scattering of the radar signal). ; location - Kerala, India.

METHODOLOGY:

- **Data Acquisition:** The first step involved acquiring the Sentinel-1A Dual Polarization Ground Range Detected (GRD) High Resolution (HR) data from the European Space Agency (ESA) Copernicus Open Access Hub.
- **Preprocessing:** The next step is to preprocess the data to remove radiometric and geometric distortions. Radiometric calibration was performed to convert the raw SAR data to backscatter coefficients, and speckle filtering was performed to reduce noise and enhance the signal-to-noise ratio.

- **NDWI Analysis:** Normalized Difference Water Index (NDWI) is used to identify and map water bodies. The NDWI is calculated by taking the difference between the Near-Infrared (NIR) and Shortwave Infrared (SWIR) bands and dividing it by their sum.

- **Flood Mapping:** The NDWI output is thresholded to create a binary water mask, which is then compared with the pre-flood extent of the water bodies to identify the flooded areas. The flood maps are then generated.

- **Time Series Analysis:** The next step involved performing a time series analysis to track changes in water levels over time. The NDWI values are plotted over time for before, during, and after flood images to identify the areas most affected by flooding.

- **Accuracy Assessment:** The final step involved assessing the accuracy of the flood map by comparing it with ground truth data collected through field visits and high-resolution optical satellite imagery.

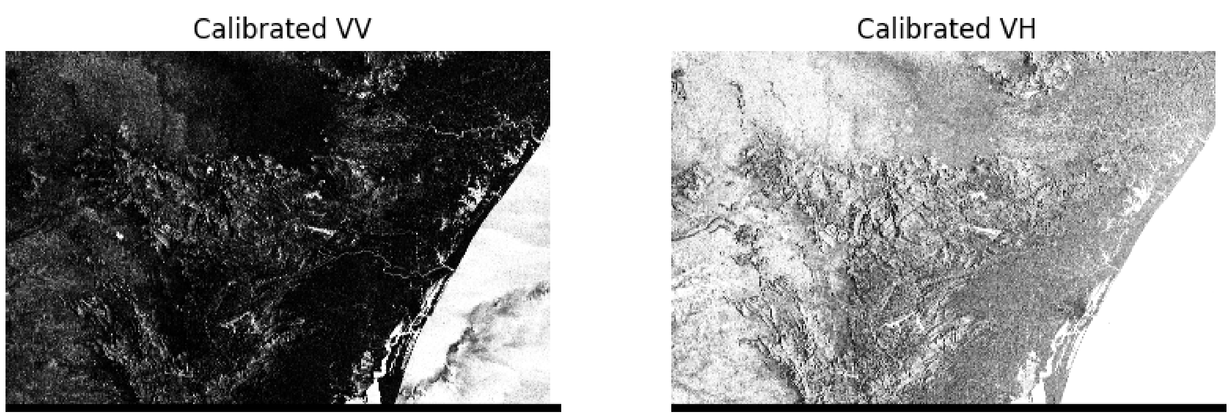
FINDINGS & IMPLICATIONS:

PREPROCESSING STEPS:

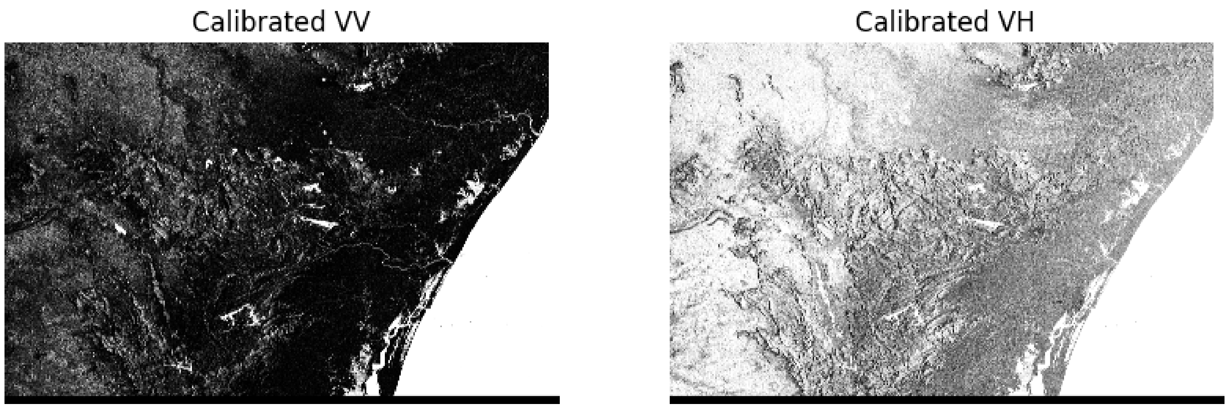
- **Radiometric Calibration:** The Sentinel-1 GRD product has already undergone radiometric calibration during the processing stage. The reason to perform additional calibration is to correct for any residual errors in the radiometric calibration that may have occurred during the processing stage. These errors may be due to various factors such as atmospheric effects, topography, or other sources of noise that were not accounted for during the initial processing stage. Therefore, it is always a good practice to assess the quality of the Sentinel-1 data and perform any necessary calibration or correction steps to ensure accurate and reliable results for your specific application.

Following are the results of applying Radiometric Calibration:

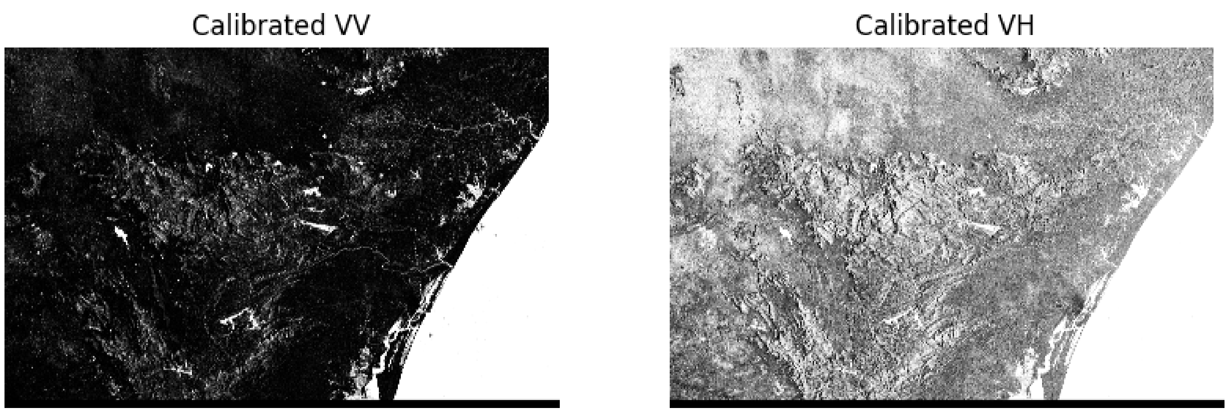
Fig 2.



(a) Before Floods



(b) During Floods



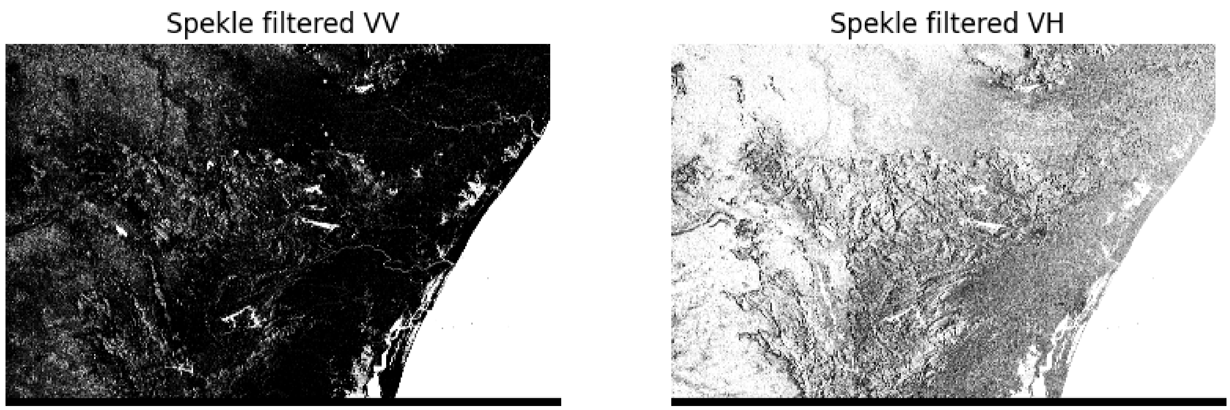
(c) After Floods

Fig2 (a) (b) (c) This calibration process has ensured that the pixel values in the images accurately reflect the true radiance or reflectance values of the objects being imaged

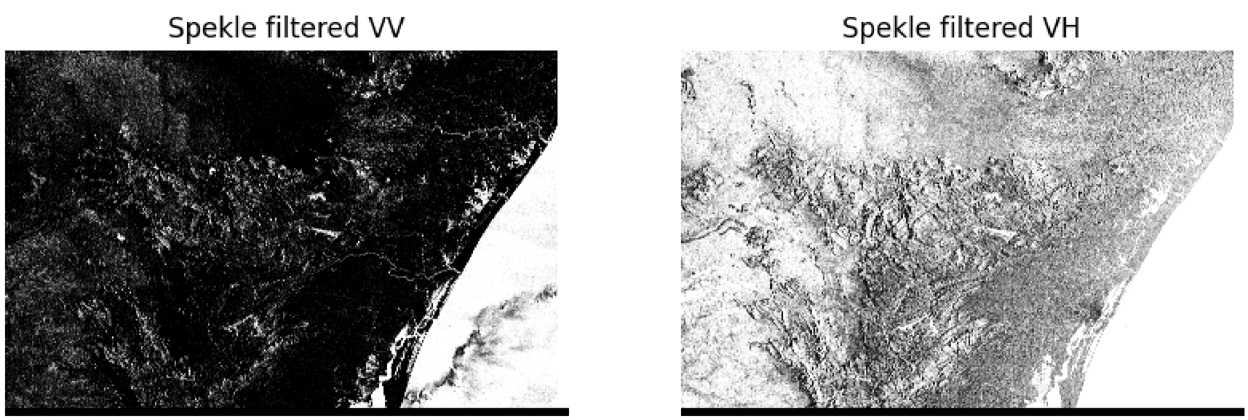
- **Speckle Filtration:** Speckle filters are important for improving the visual quality of images obtained from remote sensing systems and for enhancing the accuracy of image analysis and interpretation.It is a type of image filter used to reduce the effects of speckle noise in images. Speckle noise is a type of granular noise that is commonly observed in images obtained from remote sensing, ultrasound, and laser imaging systems.They work by smoothing the image while preserving important features such as edges and boundaries. They typically use a mathematical algorithm to analyze the image and identify areas that are likely to contain speckle noise.

Following are the results of applying Speckle filtration:

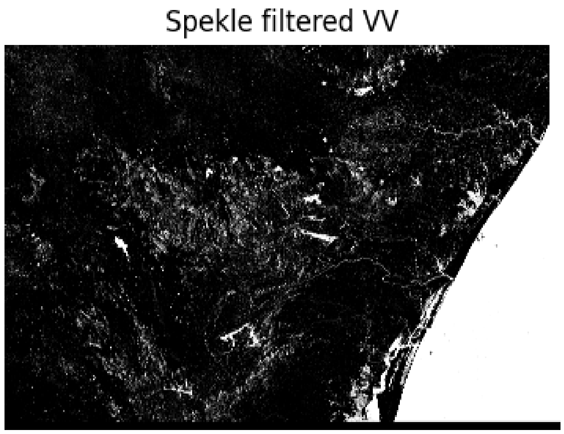
Fig 3.

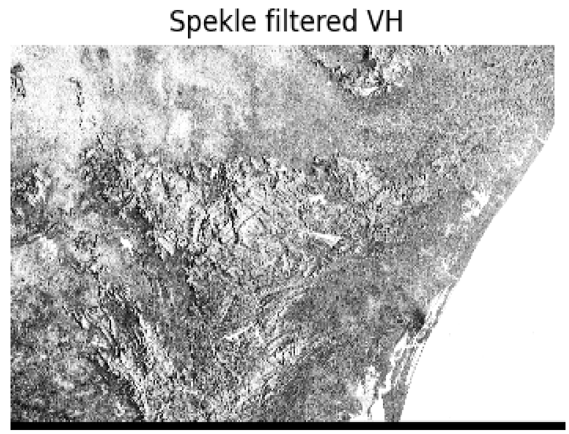


(a) Before Floods



(b) During Floods





(c) After Floods

NDWI ANALYSIS:

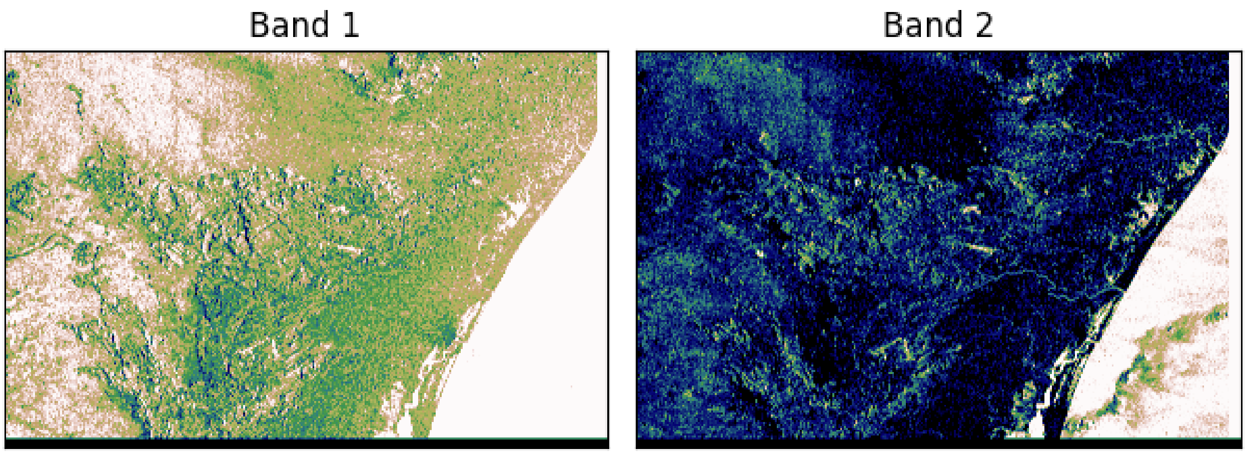
NDWI (Normalized Difference Water Index) is a commonly used index in remote sensing to map water bodies. NDWI is calculated as (Green - NIR)/(Green + NIR), where Green is the reflectance in the green part of the spectrum, and NIR is the reflectance in the near-infrared part of the spectrum.

NDWI values range from -1 to 1, where values close to 1 represent water bodies, while values close to -1 represent land surfaces. Therefore, NDWI can be used to detect the presence of water bodies in remote sensing data.

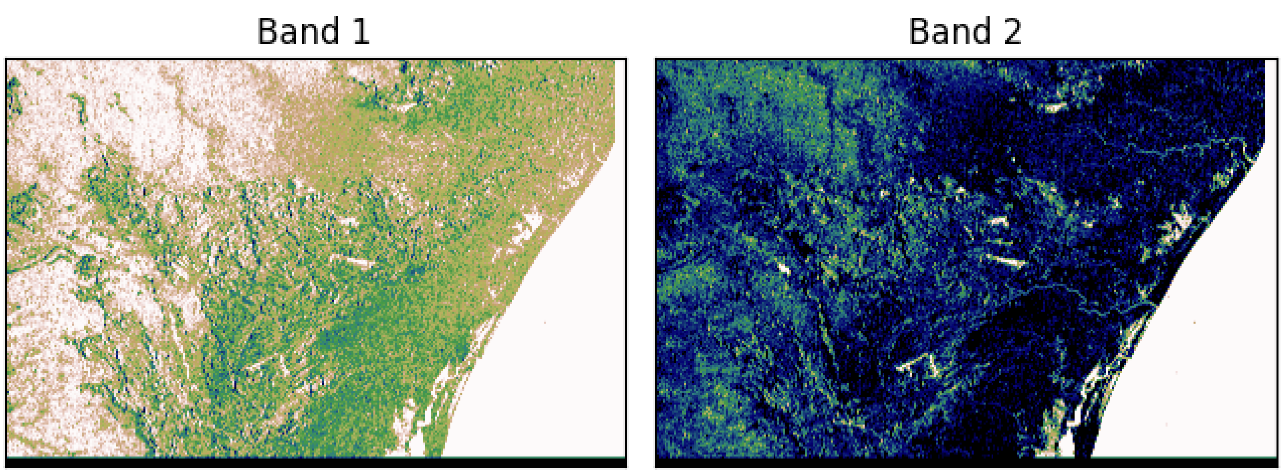
VISUALIZATION:

First, we will visualize the Multi-band raster data that can capture different spectral bands, such as red, green, blue, and near-infrared, which can be combined to create false-color images. By plotting the data in this way, we can visualize the spectral information and identify patterns and relationships that might be difficult to discern from individual bands.

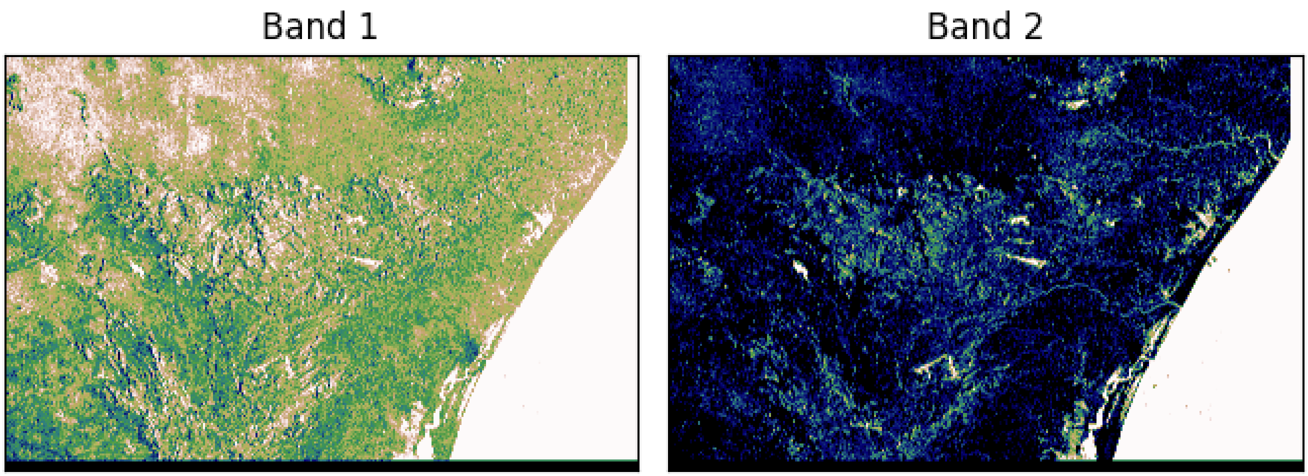
Fig 4.



(a) Before Floods



(b) During Floods



(c) After Floods

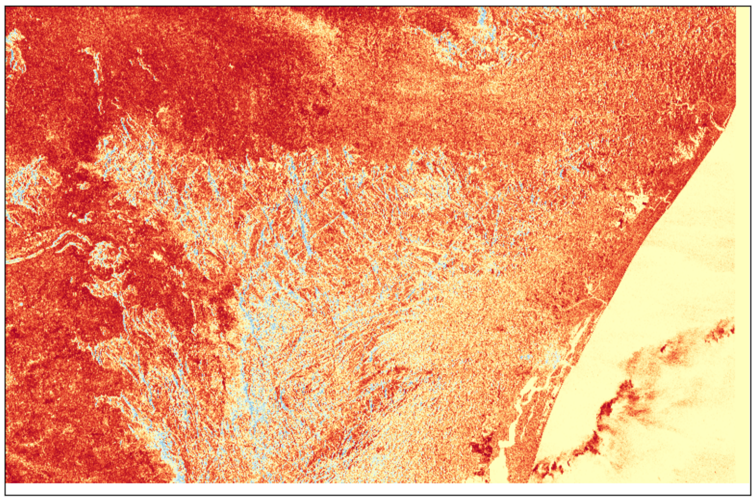
Fig 4. (a),(b) & (c) - There were slow changes observed over time.

The images show that the flood event had an impact on the landscape, with noticeable slow changes in the surface water extent and vegetation cover.

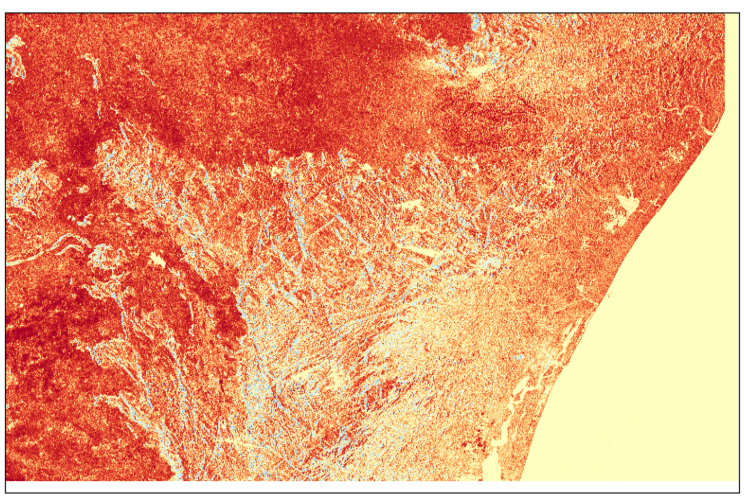
Continuous monitoring of the area using remote sensing techniques can provide valuable insights into the long-term impacts of the flood event and help inform management decisions to mitigate the risks of future flooding events.

Second, we will calculate the NDWI values for each of the scenarios, that is before , during and after flood. Visualizing NDWI values of images can provide valuable information on the spatial and temporal variations of surface water extent and dynamics, which can be used for a range of applications, such as water resource management, flood forecasting, and drought monitoring. By analyzing the changes in water dynamics over time, including trends in the water extent and changes in the timing and duration of the wet and dry seasons, effective water management strategies and policies can be developed to mitigate the risks of water-related hazards and ensure sustainable water use.

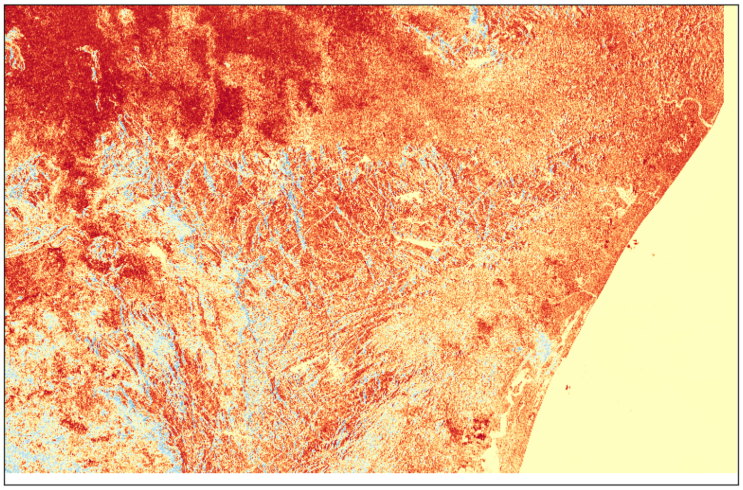
Following are the visualizations:



(a) Before Floods



(b) During Floods



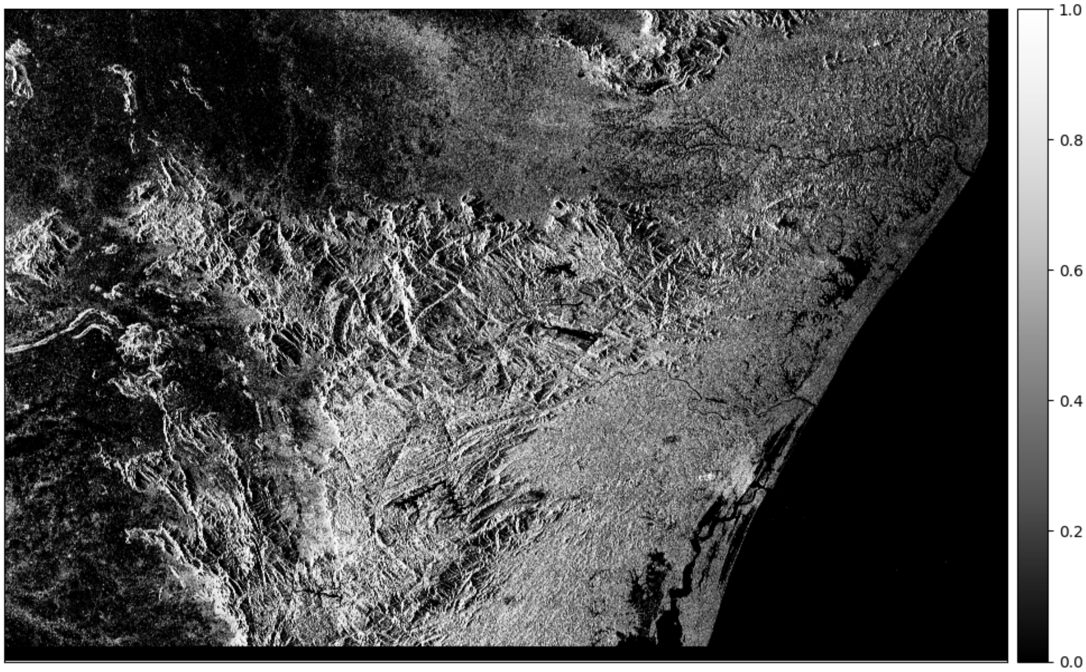
(c) After Floods

The NDWI values, which represent the water content in the pixels, show a clear increase during and after the flood event, indicating the expansion of water bodies due to the heavy rainfall. The visualizations in the RdYlBu color map highlight this increase, with blue and light colors indicating high water content and red colors indicating low water content.

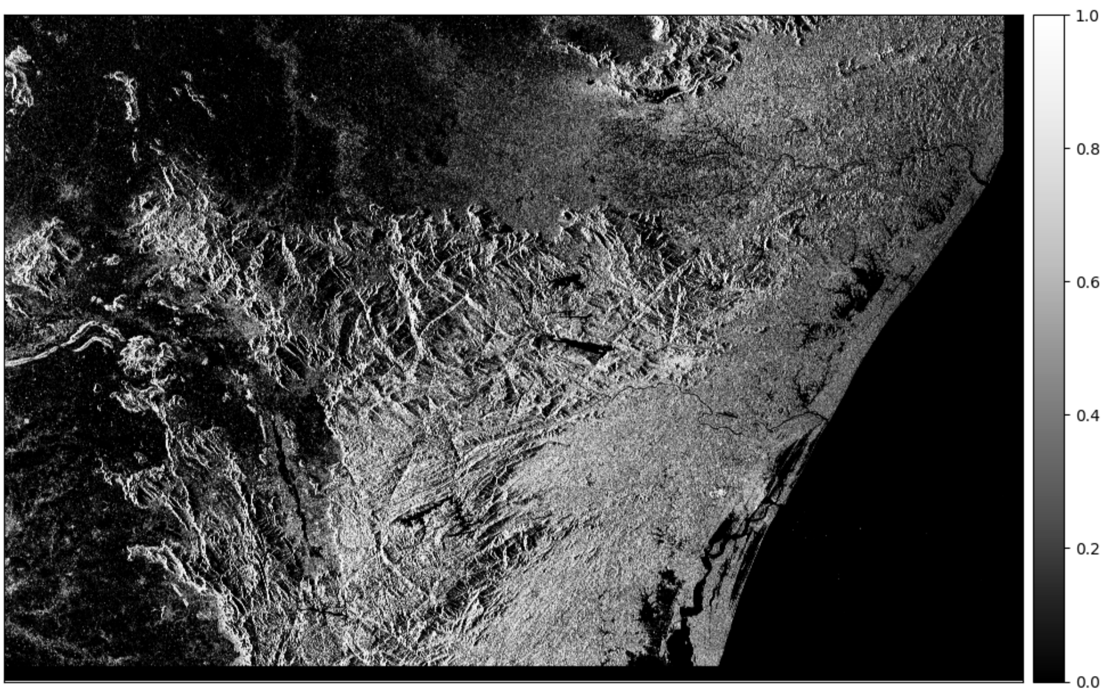
FLOOD MAPPING:

Next, let's move ahead with creating a water mask using NDWI (Normalized Difference Water Index). Creating a water mask using NDWI can help to distinguish areas of water from other land features, such as vegetation and buildings, in satellite or aerial imagery. This can be particularly useful in identifying the extent and severity of floods, as it allows for a more accurate estimation of the flooded area and can aid in emergency response efforts.

Fig 6.



(a) Before Floods



(b) During Floods

Fig6. (a) and (b), Masking has improved in identifying water visually since the area is with dense vegetation.

Further, the difference between water masks for before and during the floods are calculated. The result of the same is shown in the figure below. In this process, the input arrays are brought to the same shapes via cropping,then the difference between the two arrays is calculated, with any negative values being set to 0.

Fig 7.

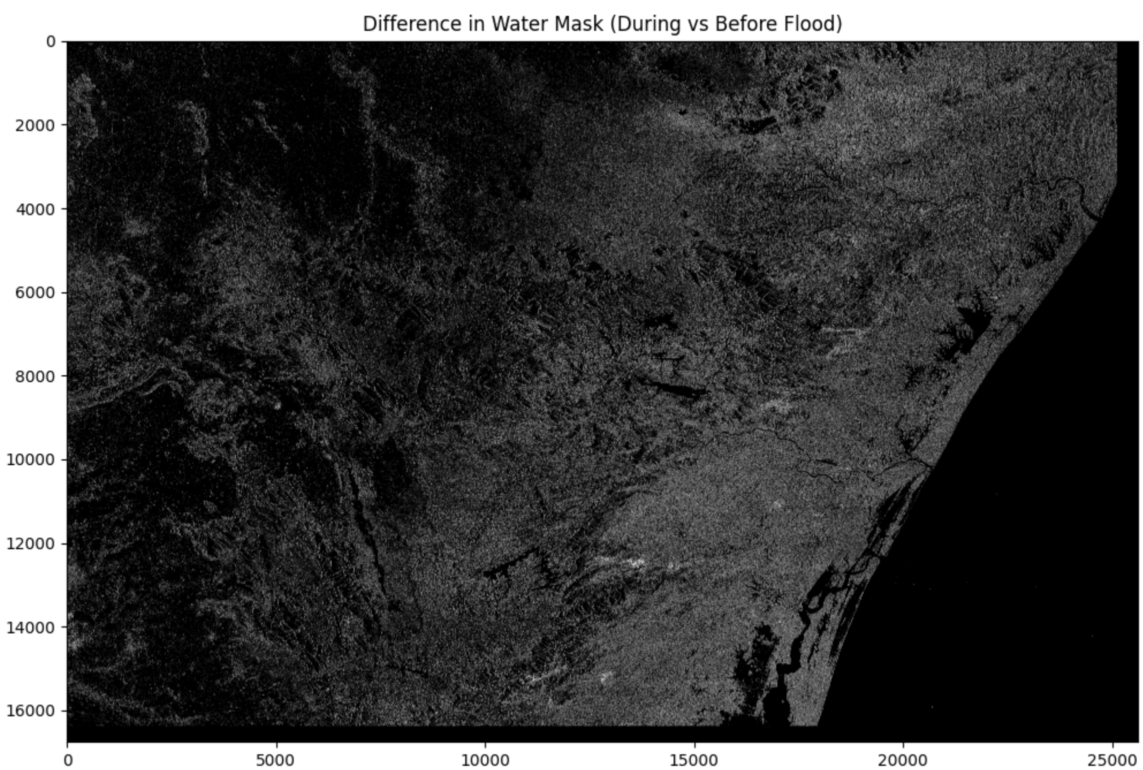


Fig 7. The presence of dark patches in the water mask difference image indicates areas that were flooded during the floods. These areas may have experienced more severe flooding or may have been inundated for a longer period of time than surrounding areas.

Next, plotting an image of a flooded area using two colormaps is attempted. The first colormap, cmap1, is used to show the water bodies in shades of green and blue. The second colormap, cmap2, is used to show the flooded areas in black with varying transparency. The function used to create the same has two inputs: the NDWI image of the flooded area and the difference in the water mask between before and during the flood.

Fig 8.

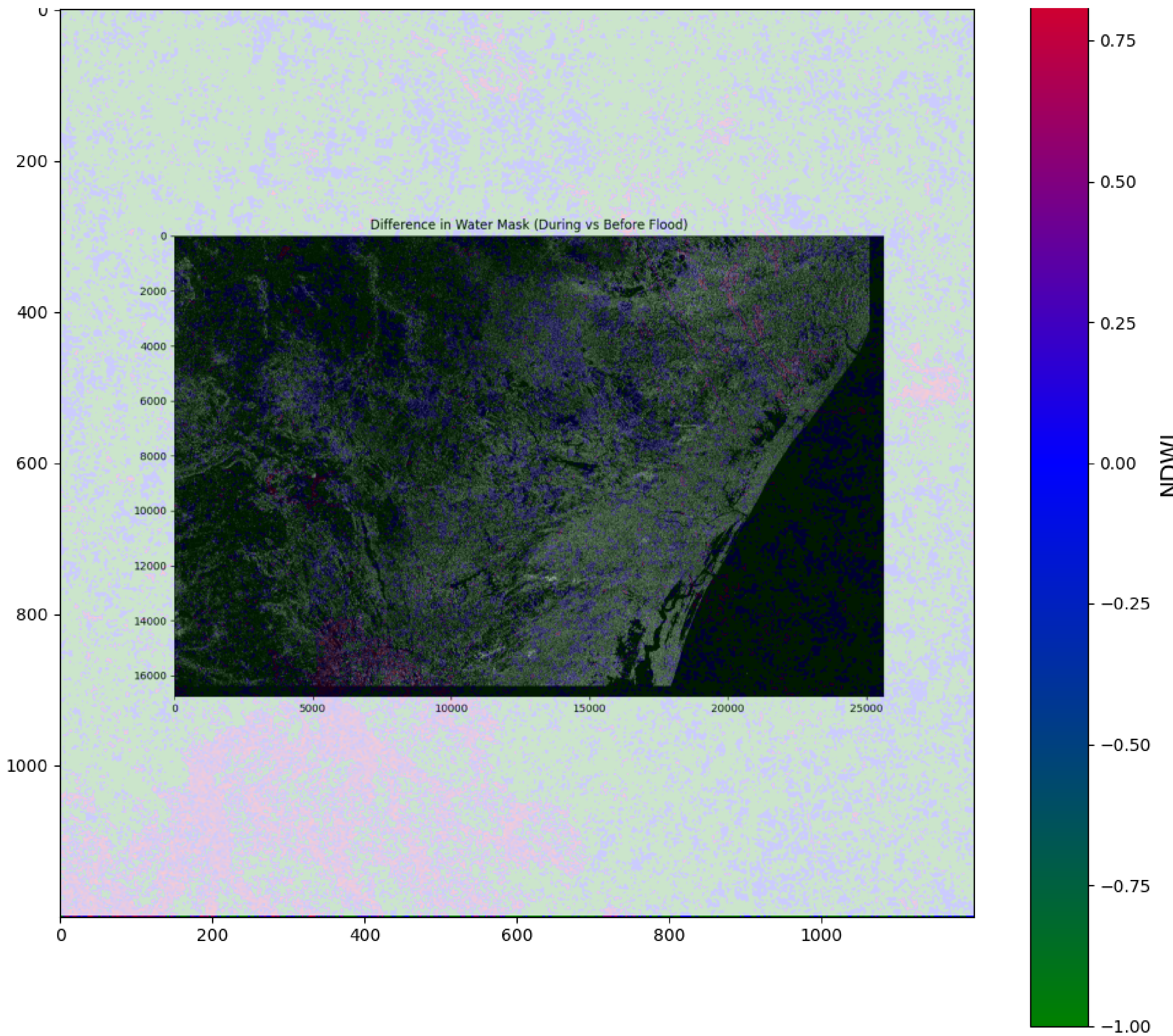


Fig8. Highlighting the areas that were not previously water bodies but were flooded. The use of two colormaps has allowed for a clear distinction between water bodies and flooded areas while also conveying the intensity of the flood through the varying levels of transparency.

The integration of data from various satellite sensors and sources has enabled the creation of precise and comprehensive flood maps, which can facilitate effective decision-making and disaster response. Our use of NDWI analysis and flood mapping techniques has yielded detailed and accurate maps of the 2018 Kerala floods. These maps have the potential to support future disaster response efforts and inform decision-making in the region. Our study demonstrates the immense value of remote sensing data in monitoring and evaluating natural disasters, underscoring the significance of sustained investment in satellite-based monitoring systems.

TIME -SERIES ANALYSIS:

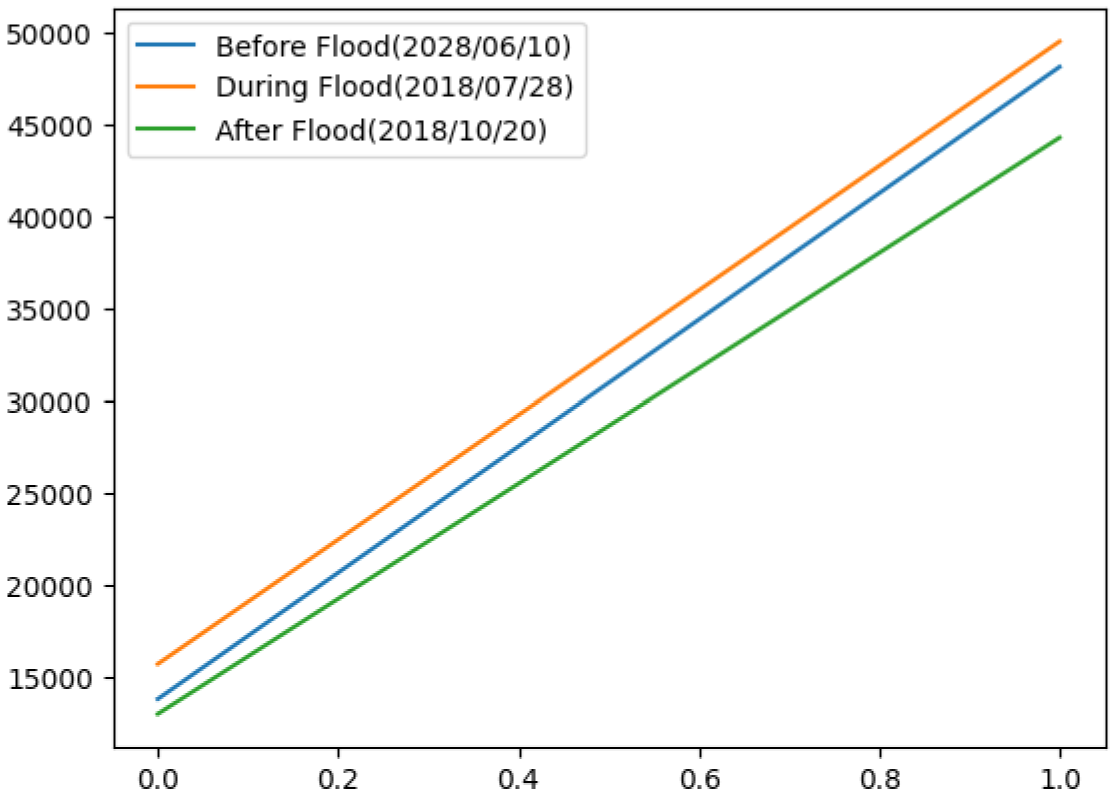
In this analysis, we will explore the capabilities of Sentinel-1 GRD images and time series analysis techniques for flood prediction and monitoring. Floods are a natural disaster that can cause severe damage to infrastructure, property, and human lives. Early detection and prediction of floods are crucial for disaster response and mitigation efforts. The high temporal and spatial resolution of Sentinel-1 SAR data enables us to monitor and track changes in flood conditions with high accuracy.

We will use time series analysis techniques to analyze the Sentinel-1 GRD images and identify changes in flood conditions over time. By studying the changes in water bodies and vegetation patterns, we can predict and monitor the onset, severity, and duration of floods. The resulting flood maps and predictions can be used by decision-makers and disaster response teams to plan and execute effective response and mitigation strategies. In addition to flood prediction, time series analysis of Sentinel-1 GRD images can also be used for other applications such as land use change detection, crop monitoring, and natural resource management. The versatility and potential of Sentinel-1 data make it an important tool for a range of remote sensing applications.

Overall, the use of Sentinel-1 data and time series analysis techniques for flood prediction and monitoring has the potential to significantly improve disaster response and mitigation efforts. By harnessing the power of remote sensing data and advanced analysis techniques, we can better understand and manage natural disasters like floods, ultimately leading to safer and more resilient communities.

Firstly, the intensity time-series for each period is computed, linear regression for each intensity time-series is being plotted and further likelihood of a flood based on the linear regression coefficients is predicted. The following figure represents the results.

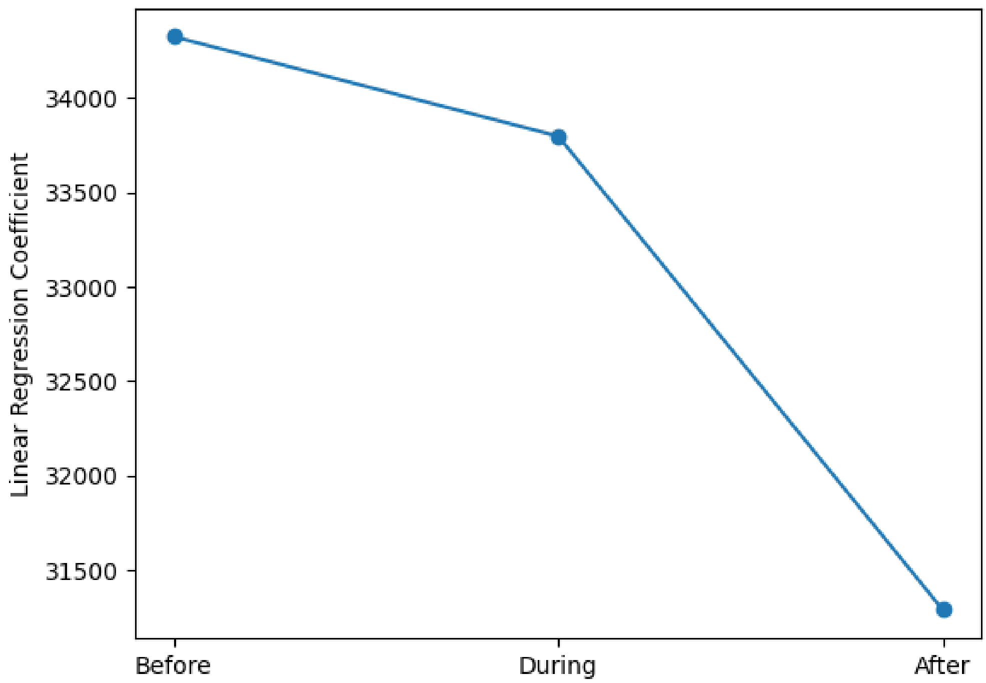
Fig 9.



The time series plot above presents a clear visualization of the dynamic variations in the intensity of a specific variable over time. It demonstrates that the intensity levels exhibit a distinct pattern, wherein the intensity gradually rises before the onset of the flood, reaches its maximum during the flood, and then gradually declines after the flood recedes. Such a pattern has vital implications for the variable being measured, and it could significantly affect the surrounding ecosystem. A thorough comprehension of the intensity changes pre, during, and post-flood is essential for predicting the ecological impact of floods and devising appropriate management measures.

Secondly, the linear regression coefficients before, during, and after the floods are plotted. This allows for visualization of how the coefficient values change over time, which provides insight into the relationship between the variable and the flood event. The x-axis represents the time periods (before, during, and after), while the y-axis displays the linear regression coefficients for the variable being analyzed. The results are shown below.

Fig 10.



The amount and direction of changes in several elements, such as water level, flow rate, sediment transport, and water quality, are shown by the linear coefficients before, during, and after a flood.

According to the stated statement,it can be observed that the linear coefficient is larger before the flood than during the flood, indicating that these elements are changing at a faster rate before the flood than during the flood. The amount and direction of changes in several elements, such as water level, flow rate, sediment transport, and water quality, are shown by the linear coefficients before, during, and after a flood. According to the stated statement, the linear coefficient is larger before the flood than during the flood, indicating that these elements are changing at a faster rate before the flood than during the flood.

CONCLUSION:

The Kerala floods of 2018 were a catastrophic event that caused significant damage and loss of life. To better understand the extent of the flooding and its impacts, various remote sensing techniques such as preprocessing, NDWI analysis, flood mapping, and time series analysis were used. The combination of these techniques provided valuable insights into the extent and severity of the flooding, which was crucial for emergency response and relief efforts. It also highlighted the importance of remote sensing in disaster management and the need for continued research in this field to better prepare for and respond to future natural disasters. By continuing to refine and improve these techniques, we can better understand and prepare for the impacts of natural disasters like floods.