Assignment 2: Report

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1 Introduction

Forest fires pose a significant ecological and economic threat in India, particularly in regions with dense and diverse vegetation like the Western Ghats, the Himalayas, and parts of Central India. These fires often disrupt local ecosystems, impacting biodiversity, soil quality, and air quality, while also posing risks to human settlements and natural resources. With climate change, prolonged dry seasons, and human encroachment, the frequency and intensity of forest fires are increasing, highlighting the need for effective monitoring and management strategies.
Satellite-based indices, particularly the Normalized Burn Ratio (NBR) and its derivative, the Differenced Normalized Burn Ratio (dNBR), have emerged as essential tools for assessing the impact and extent of these fires. These indices are valued for their sensitivity to changes in vegetation cover and surface characteristics post-fire, allowing for detailed burn severity assessments. However, the effectiveness of NBR and dNBR can vary across different geographic and vegetative contexts, which raises questions about their applicability in India's diverse landscapes. This report will examine the utility of NBR and dNBR across various geographies and vegetation types in India, comparing them to other burn area indices, to determine their strengths and limitations in accurately mapping fire-burned areas in this unique environmental setting.

2 Data preprocessing

To assess fire-burned areas with accuracy on Google Earth Engine (GEE) using the provided shapefiles, we employed a series of preprocessing steps to prepare and visualize the data effectively. The dataset included:

1. Protected Areas Shapefile (polygon): Representing the boundaries of designated protected forest areas in India.
2. Active Fire Locations Shapefile (point): Indicating specific geographic locations of active fires within these protected areas.

To accurately select regions of interest on GEE in relation to these shapefiles, we needed to overlay a political map of India. This allowed us to identify nearby cities or towns to contextualize fire locations and ensure accurate plotting on GEE. The following steps were carried out:

1. **Overlaying the Polygon Shapefile with an Indian Political Shapefile:** This overlay helped align the protected areas with familiar geographic boundaries, enabling better interpretation of the data relative to cities and administrative regions.

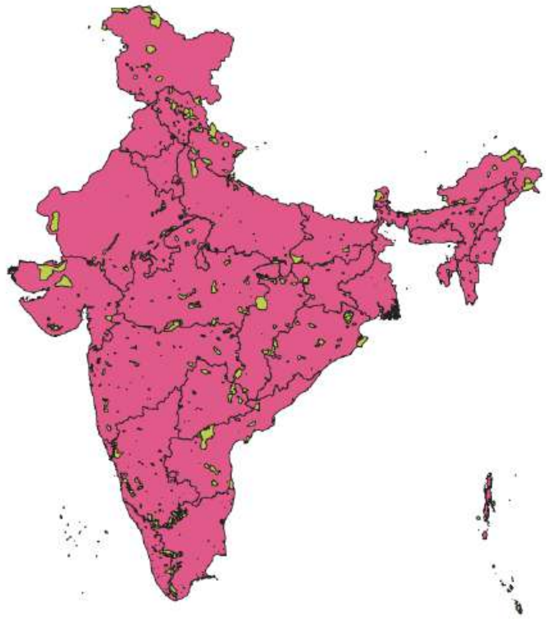


Figure 1: Overlaying the Polygon Shapefile with an Indian Political Shapefile

2. **Classifying Active Fire Points by Forest Type:** We categorized the points in the active fire locations shapefile based on forest type, facilitating an understanding of fire impacts on different vegetation classes.

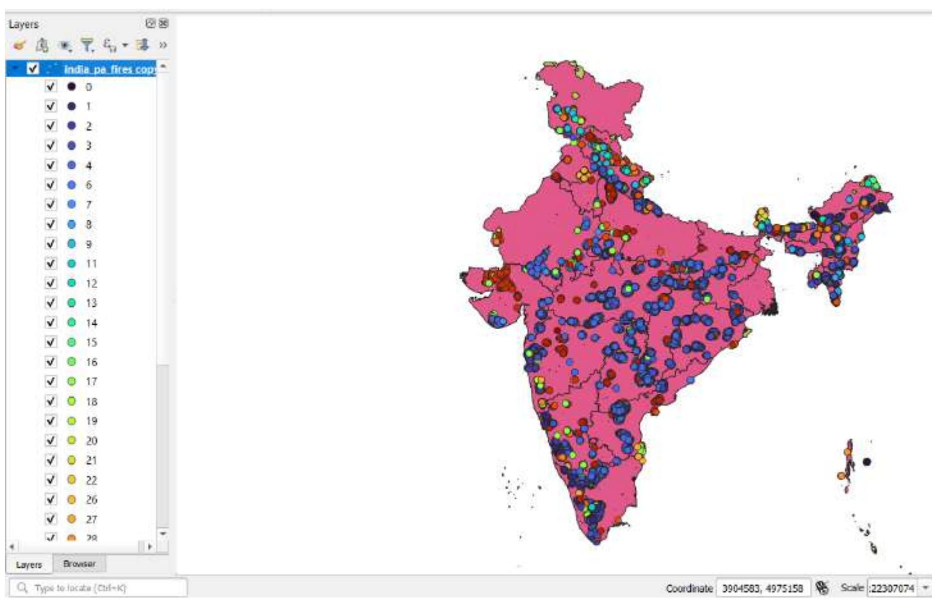
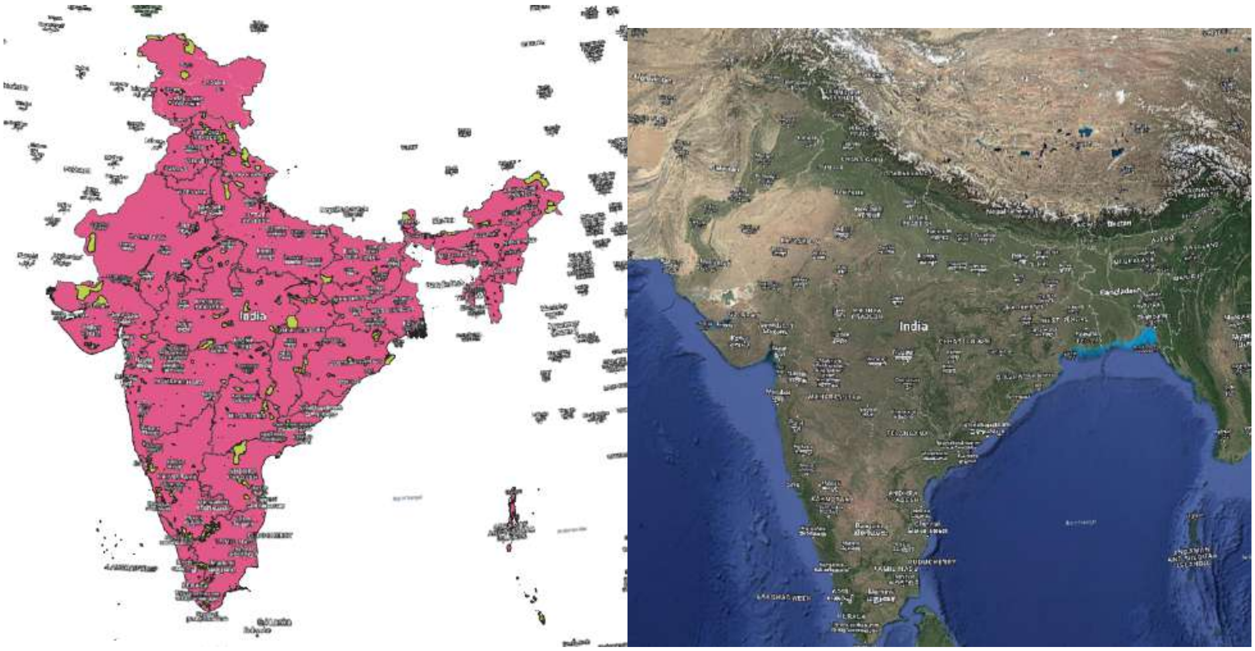


Figure 2: Classifying Active Fire Points by Forest Type

3. **QuickMapServices Plugin Installation:** We installed the QuickMapServices (QMS) plugin to enhance mapping capabilities, enabling integration of additional map layers for our analysis.

4. **Adding Google Satellite and Label Layers:** Through QMS, we accessed the Google Satellite layer for high-resolution imagery and the Google Labels layer to identify city names. This setup provided a reference for identifying towns and landmarks relative to fire points, simulating a GEE-like view.



(a) Overlayed with Google Labels (b) Overlayed with Google labels & satellite view

Figure 3: Comparison of overlays with Google Labels and Google Labels with Satellite View

5. **Overlaying the Final Map with Active Fire Locations:** By combining the satellite imagery, city labels, and protected area boundaries, we overlaid the active fire locations shapefile to pinpoint exact fire locations within protected zones and their proximity to nearby urban centers.

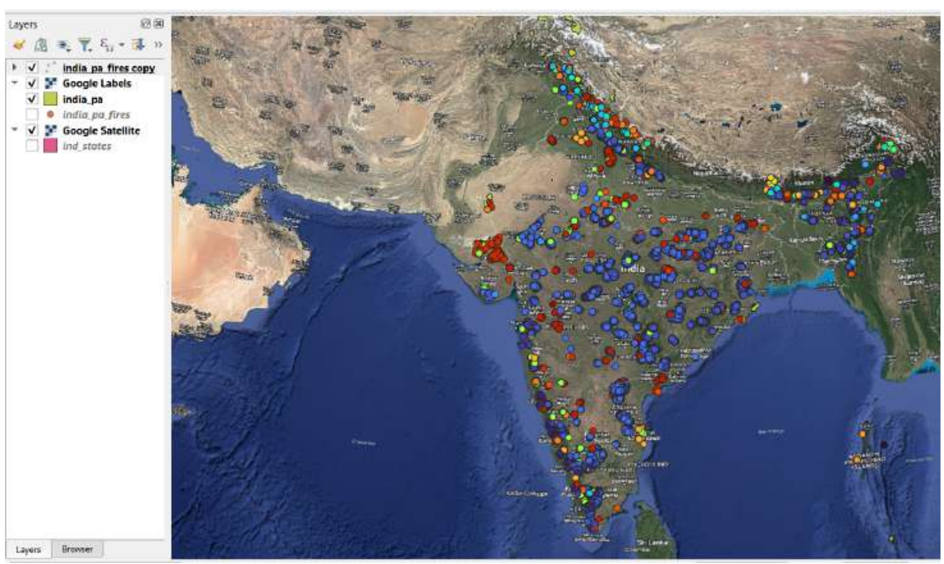


Figure 4: Final output after preprocessing

These steps produced a map closely resembling the Google Earth Engine interface, enabling precise visualization of fire-affected areas and aiding in the subsequent analysis of burn severity across various regions.

3 Regions of Interest

For this analysis, three diverse regions in India have been selected to evaluate the effectiveness of the DNBR/NBR indices in delineating fire-burned areas across different geographies and vegetation types. These regions include:

1. Near Dada, Uttarakhand (Western Himalayas)

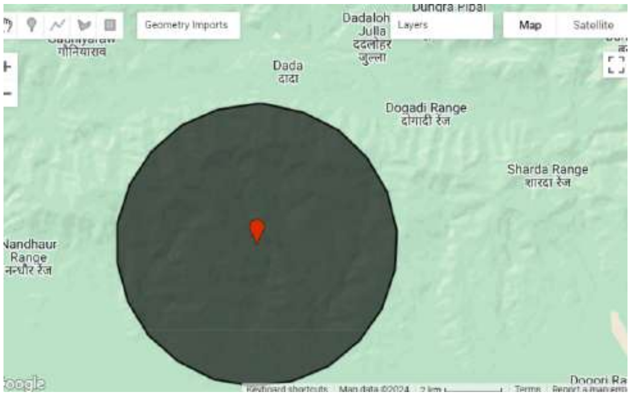


Figure 5: Area near Dada, Uttarakhand

2. Shiroli, Karnataka (Western Ghats)

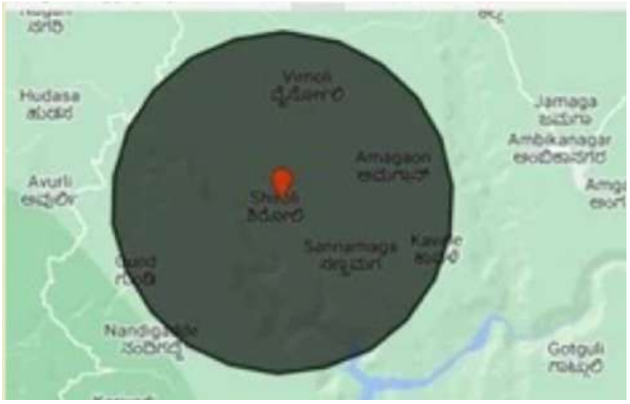


Figure 6: Area around Shiroli, Karnataka

3. Near Kunda, Assam (Northeast India)

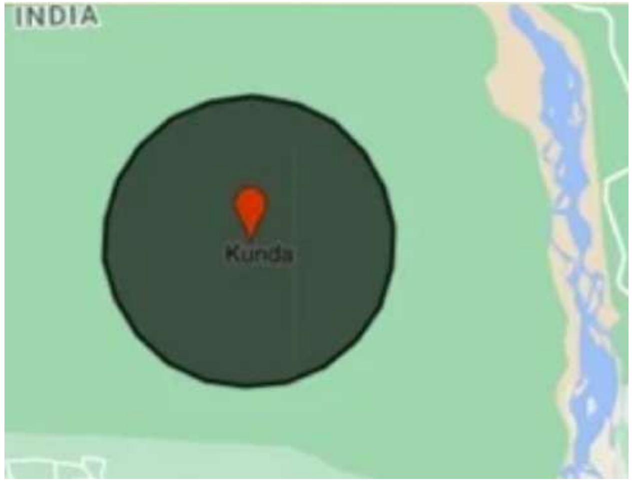


Figure 7: Area around Kunda, Assam

4 Rationale Behind Choosing the ROIs

The regions selected for this study—Uttarakhand, Karnataka, and Assam—represent distinct forest and vegetation types that provide valuable insights into the behavior of fires across different ecological settings.

1. Uttarakhand and Karnataka: The ROIs in these regions are predominantly populated with Type 3 and Type 4 forests, which correspond to moist and dry deciduous forests, respectively, as per the forest type legend. These forests experience seasonal dryness, where leaf litter accumulates during the dry season, creating significant fuel for fires. Additionally, the high temperatures during the pre-monsoon months increase the likelihood of ignition in both moist and dry deciduous forests. The dense understory vegetation in these regions further contributes to the fire load, particularly when dry, making these areas more susceptible to fire spread.
2. Assam: The ROI in Assam is primarily composed of grasslands (Type 29), which are also prone to fires due to the accumulation of dry vegetation during the dry season. Grasslands, while having different structural characteristics from forests, still experience similar seasonal dryness and high temperatures, which can result in large fire events.

These selected regions are diverse in terms of forest type, climatic conditions, and vegetation structure, offering a comprehensive basis for evaluating the effectiveness of DNBR/NBR indices in delineating fire-burned areas across various types of ecosystems.

5 Indices chosen for analysis and why?

For this study, several indices were chosen to evaluate the effectiveness of fire detection and burn severity mapping in the selected regions. The selected indices, which include pre- and post-fire versions, provide a comprehensive understanding of the changes in vegetation and surface properties before and after the fire event. The following indices were chosen for analysis:

- **Normalized Burn Ratio (NBR) and Differenced Normalized Burn Ratio (dNBR)**:
  - *NBR* is a commonly used index to detect burn severity by comparing near-infrared (NIR) and shortwave infrared (SWIR) bands. It is effective in identifying fire-impacted areas and their severity. The formula for NBR is:

$$\mathrm{NBR} = \frac{\rho_{\mathrm{NIR}} - \rho_{\mathrm{SWIR2}}}{\rho_{\mathrm{NIR}} + \rho_{\mathrm{SWIR2}}}$$

- *dNBR* is the difference between the pre- and post-fire NBR, which allows for a clearer delineation of burned areas and their severity levels. This index is widely used in remote sensing for post-fire assessments. The formula of dNBR is:

$$\mathrm{dNBR} = \mathrm{NBR}_{\mathrm{pre}} - \mathrm{NBR}_{\mathrm{post}}$$

- To refine our burn severity analysis, we applied an *NDWI* (Normalized Difference Water Index) mask to exclude water bodies from the calculation. This ensures that water bodies, which could potentially distort the dNBR analysis, are not included in the burn severity assessment. The *masked dNBR* is particularly useful in regions where water bodies are prominent, helping to avoid false-positive results in burn detection.

• **Modified Burn Ratio (MIRBI) and Differenced Modified Burn Ratio (dMIRBI)**:

- *MIRBI* is an essential index for understanding the susceptibility and characteristics of burned surfaces. It is designed to enhance fire detection by combining the Medium Infrared (MIR) and NIR bands, focusing on the spectral differences between burned and unburned areas. This index is useful for mapping fire-impacted areas in regions with varying vegetation types.
- MIRBI utilizes two shortwave infrared (SWIR) bands to detect burned surfaces effectively. These bands respond well to soil and dry vegetation characteristics, making
- MIRBI a complementary index to NBR. The formula of MIRBI is:

$$\mathrm{MIRBI} = 10 \times \rho_{\mathrm{SWIR2}} - 9.8 \times \rho_{\mathrm{SWIR1}} + 2$$

  While NBR is effective in identifying burn severity, MIRBI focuses more on the characteristics of the burned surfaces and highlights fire-susceptible regions post-burn.
- *dMIRBI* compares the pre- and post-fire MIRBI to capture burn severity, similar to dNBR but with a focus on the MIR band, which is sensitive to changes in vegetation and surface characteristics after fires. The formula for dMIRBI is:

$$\mathrm{dMIRBI} = \mathrm{MIRBI}_{\mathrm{pre}} - \mathrm{MIRBI}_{\mathrm{post}}$$

• **Pre- and Post-Fire False Color Composite (FCC)**:

- *FCC* is a combination of multiple bands, often involving NIR, red, and SWIR bands, to enhance the visibility of fire-impacted areas. By comparing pre- and post-fire FCCs, changes in vegetation health, structure, and burn severity can be easily visualized.

• **Normalized Difference Vegetation Index (NDVI)**:

- *NDVI* is widely used to assess vegetation health by comparing the difference between NIR and red bands. It uses red and near-infrared bands to measure vegetation density and health which helps us in understanding how the fire affected vegetation cover. A significant drop in NDVI values post-fire indicates a loss of vegetation and damage to the landscape. The formula of NDVI is:

$$\mathrm{NDVI} = \frac{\rho_{\mathrm{NIR}} - \rho_{\mathrm{RED}}}{\rho_{\mathrm{NIR}} + \rho_{\mathrm{RED}}}$$

- Both pre- and post-fire *NDVI* values are analyzed to determine the extent of vegetation loss and to identify areas severely impacted by the fire.
- This index complements NBR by confirming vegetation reduction but is less specific to fire damage itself.

• **Burn Area Index (BAI)**:

– *BAI* is used to detect fire-impacted areas based on spectral reflectance differences in the red and SWIR bands. It is particularly useful in identifying the extent of burned areas and is sensitive to both vegetation and soil changes following a fire. The formula for BAI is:

$$\text{BAI} = \frac{1}{(\rho_{\text{NIR}} - 0.06)^2 + (\rho_{\text{RED}} - 0.1)^2}$$

– It is particularly useful for tracking potential regrowth in regions like Kunda, where regrowth has been observed.

– In regions such as Kunda, where vegetation is regrowing after fire, BAI helps confirm this recovery, showing lower burn signatures over time.

– BAI complements NBR by tracking the burn presence and helping to confirm post-fire regrowth patterns.

– Like the other indices, pre- and post-fire *BAI* comparisons help to assess burn severity and the effectiveness of fire detection.

These indices were chosen due to their ability to capture a range of fire characteristics, including burn severity, fire extent, and vegetation loss. By analyzing both pre- and post-fire data, we can gain a comprehensive understanding of how each region responds to fire events and how effectively each index detects fire-affected areas across different geographies and vegetation types.

6 Choice of Satellite and Time Duration

For this study, **Landsat 9** imagery was selected due to its high spatial and spectral resolution, which is ideal for monitoring land surface changes and vegetation health. Landsat 9 offers advanced sensors capable of capturing the spectral bands needed to calculate indices like NBR, MIRBI, NDVI, and BAI, which are essential for fire and vegetation assessments. Additionally, Landsat 9 provides a revisit time of 16 days, allowing consistent temporal coverage to monitor both pre- and post-fire conditions.

The **pre-fire period** from *April 1, 2022, to July 31, 2022,* and the **post-fire period** from *April 1, 2023, to July 31, 2023,* were selected to capture the vegetation conditions during similar seasonal cycles. This time frame avoids seasonal variations, ensuring that vegetation differences observed are primarily due to the fire impact rather than seasonal growth cycles. This period aligns with typical dry seasons in the regions studied, maximizing the contrast between vegetation and burned areas.

Also, the choice of these specific months (April to July) is based on the typical fire season and vegetation conditions in many regions, especially in tropical and subtropical areas. Fires are more common during or immediately before dry seasons when vegetation is more susceptible to burning due to lower moisture levels. By selecting April to July, the analysis captures vegetation conditions during a period likely impacted by recent fires or heightened fire risk.

7 Analysis on Google Earth Engine

This study was conducted using **Google Earth Engine (GEE)**, a robust cloud-based geospatial analysis platform that facilitates large-scale processing and visualization of satellite imagery. GEE's extensive data catalog and computational capabilities make it ideal for rapid environmental analysis. For data, we selected the **LANDSAT/LC09/C02/T1_L2** dataset from the Landsat 9 mission, known for its high spatial and spectral resolution. This dataset is particularly suited for monitoring land surface changes and assessing fire impacts on vegetation.

Our **Areas of Interest (AOI)** included multiple regions with distinct geographic and climatic conditions, allowing us to evaluate fire impact on various vegetation types and landscapes. GEE was chosen for its **scalability**, enabling efficient processing of large datasets without local hardware constraints, and **data accessibility**, providing direct access to up-to-date satellite data from missions like Landsat, MODIS, and Sentinel.

The objective was to calculate pre-fire and post-fire indices for each AOI to analyze vegetation loss, burn severity, and potential regrowth. By leveraging GEE's advanced analytical tools, such as built-in functions for calculating complex indices (NBR, MIRBI, NDVI, and BAI), we ensured accurate and efficient analysis across diverse landscapes.

7.1 Near Kunda, Assam (Northeast India)

7.1.1 False Color Composite (FCC

In analyzing the Kunda area with a 5 km buffer, we focused on comparing the pre-fire and post-fire False Color Composite (FCC) imagery.

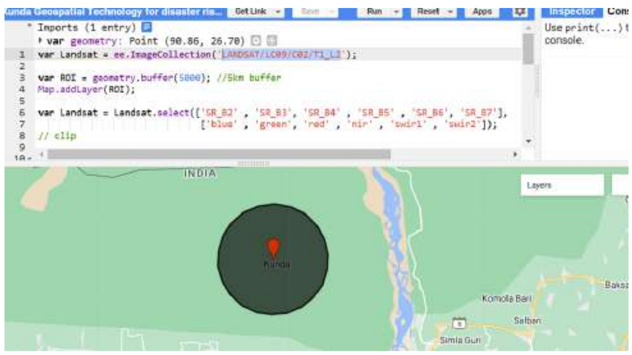


Figure 8: Kunda 5km Buffer

- **Pre-Fire FCC (green)**:
  - In the Pre-Fire FCC, the dominant green color around the point of interest indicates healthy vegetation.

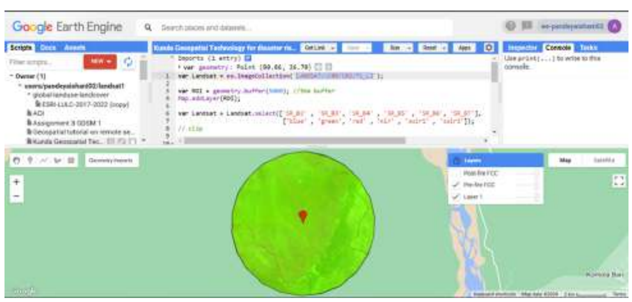


Figure 9: Pre-Fire FCC of Kunda

- **Post-Fire FCC (grey)**:
  - While in the Post-Fire FCC, the same area shows a shift towards a greyish tone. This color shift suggests a reduction in vegetation, likely due to fire, as green typically represents vegetated areas and grey indicates reduced vegetation cover or bare soil.

  This change in FCC imagery visually indicates **potential fire impact in the region**, where vegetation health seems compromised post-fire. This analysis is the first step in identifying and assessing fire-affected zones.

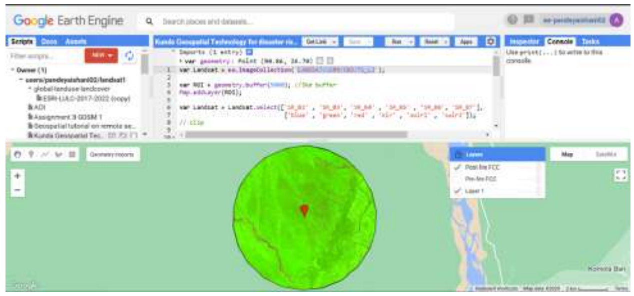


Figure 10: Post-Fire FCC of Kunda

7.1.2 Normalized Burn Ratio (NBR)

In the analysis of Kunda, Assam, the Normalized Burn Ratio (NBR) was utilized to evaluate vegetation conditions before and after the fire event, with a focus on a 5 km buffer zone.

The high NBR values (darker tones - highest at black) indicate healthy vegetation at this location. Similarly, the lower NBR values(lighter tones - lowest at white) indicate loss of vegetation.

- **Pre-Fire NBR (white at point of interest)**:
  - The low NBR values (white color) indicate reduced vegetation or vegetation loss in the pre-fire period. This may suggest that the "pre-fire" period **actually reflects an ongoing fire**, which diminished vegetation cover at this time.

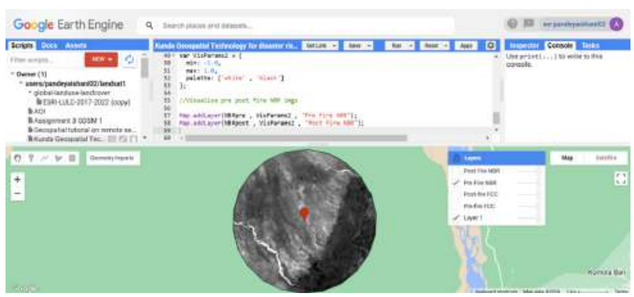


Figure 11: Pre-Fire NBR for Kunda

- **Post-Fire NBR (black at point of interest)**:
  - In contrast, the post-fire period displays higher NBR values (black color), signifying healthy vegetation cover. This suggests substantial regrowth in the region after the fire, which is unusual yet possible due to the area's high rainfall and conducive climate.

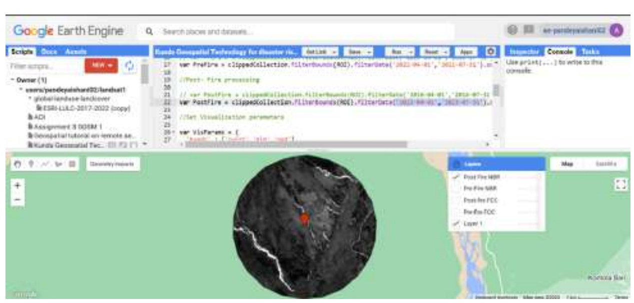


Figure 12: Post-Fire NBR for Kunda

- **Differenced NBR (dNBR - yellow at point of interest)**:
  - The dNBR shows yellow color, indicating mild burn severity. This yellow shade suggests some vegetation loss, although not at the highest severity levels.

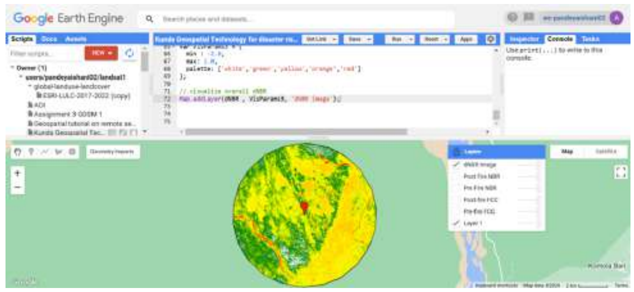


Figure 13: dNBR for Kunda

- **Masked dNBR (yellow)**:
  - By applying a water mask, we refined the analysis to focus on land areas, resulting in a yellow color for dNBR at the location. This suggests moderate burn severity and potential regrowth, supported by Assam's high rainfall, which may accelerate vegetation recovery in fire-affected regions.

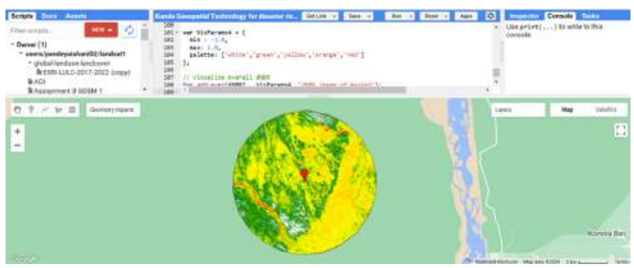


Figure 14: Masked dNBR for Kunda

This analysis suggests that while the fire impacted the area and the area did suffer mid vegetation loss(supported by dNBR), Kunda's favourable climate conditions, including high rainfall, likely supported and enabled post-fire regrowth, as observed in the Post- Fire NBR results.

7.1.3 Mid-Infrared Burn Index (MIRBI)

The **Mid-Infrared Burn Index (MIRBI)** is a spectral index tailored for identifying and assessing burn severity in fire-impacted regions. By focusing on shortwave infrared (SWIR) bands, MIRBI effectively highlights areas where fires have significantly altered surface properties. The MIRBI formula is:

$$\text{MIRBI} = 10 \times \rho_{\text{SWIR2}} - 9.8 \times \rho_{\text{SWIR1}} + 2 \tag{1}$$

where:

- ρ_{SWIR2} represents reflectance in the SWIR2 band, sensitive to ash and char post-fire.
- ρ_{SWIR1} denotes reflectance in the SWIR1 band, associated with moisture levels in soil and vegetation.

High MIRBI values signify severe burn impact, showing low moisture and increased ash, while **lower MIRBI values indicate healthy, moist vegetation or minimal fire impact** .

Lowest MIRBI value is represented by White and highest MIRBI value is represented by Red. Yellow and Orange are moderate MIRBI values.

So, **in order of increasing MIRBI values, the colour representation is White <Yellow <Orange <red**

dMIRBI highlights areas where MIRBI changed, indicating shifts in fire susceptibility or surface conditions due to the fire. High positive dMIRBI values (red) in the visualization indicate a significant change in MIRBI after the fire, suggesting burn severity. Whereas, negative values (blue) suggests moisture recovery or a change in surface reflectance that reduces fire susceptibility.

So, in order of increasing dMIRBI calues, the colour representation is **blue <white <orange <red**

- **Pre-Fire MIRBI (Yellow)**: At the area point in the pre-fire period, MIRBI shows a yellow color, suggesting moderate susceptibility to burning or a dry surface condition.

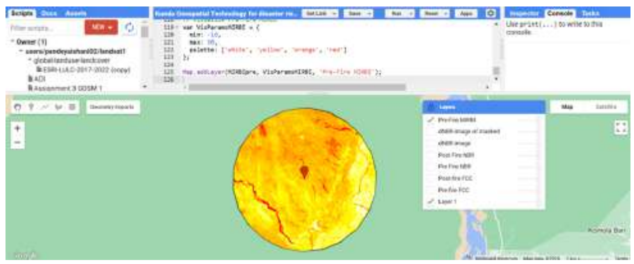


Figure 15: Pre-Fire MIRBI for Kunda

- **Post-Fire MIRBI (Orange)**: Post-fire, the MIRBI value increases to orange, indicating intensified burn effects with more exposed ash and reduced moisture.

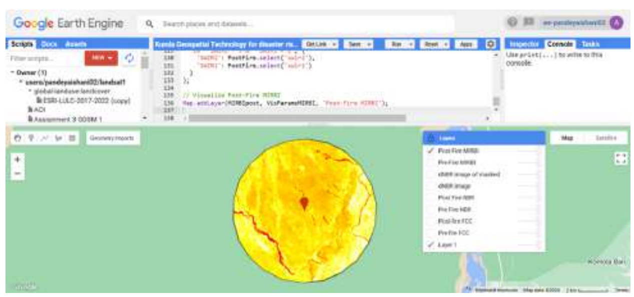


Figure 16: Post-Fire MIRBI for Kunda

- **dMIRBI (Difference - Orange)**: The dMIRBI shows an orange color (positive value - possibly indicating newly exposed or dry materials due to burning), representing a significant increase in burn severity. This rise reflects surface changes due to fire, with exposed ash and decreased vegetation moisture in the post-fire phase.

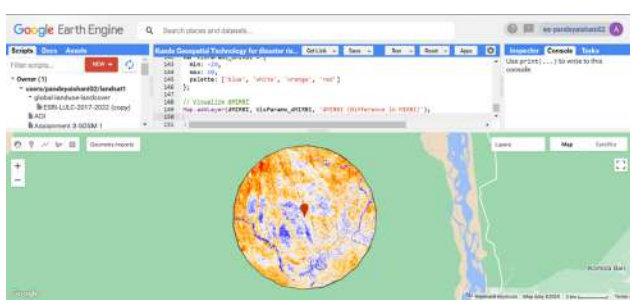


Figure 17: dMIRBI for Kunda

The analysis indicates that the Kunda area, post-fire, has experienced a pronounced burn effect, with high burn susceptibility visible in the elevated MIRBI values.

7.1.4 Normalized Difference Vegetation Index (NDVI)

The Normalized Difference Vegetation Index (NDVI) is a spectral index that measures vegetation health by analyzing the difference between near-infrared (NIR) and red bands. High NDVI values indicate healthy, dense vegetation, while lower values indicate sparse or unhealthy vegetation.

In the below figures, highest NDVI values are represented as Green and lowest NDVI values are represented as Blue. White represents moderate NDVI. So, in terms of increasing NDVI - the colour representation is **Blue <White <Green**

For dNDVI, the colour representation increases as **Red <White <Green**

- **Pre-Fire NDVI (White):**
  - In the Pre-Fire NDVI image, the area around the point of interest appears white, indicating relatively low vegetation density or health prior to the fire. This could suggest that the vegetation in this area was already compromised, possibly due to environmental conditions or ongoing fire impacts.

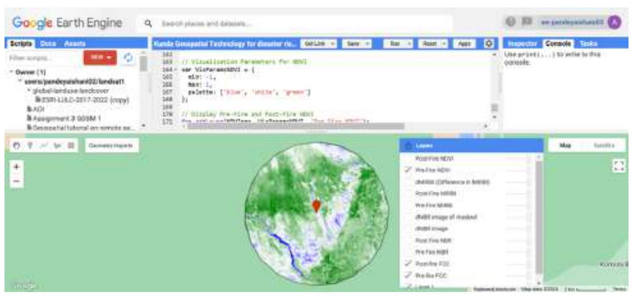


Figure 18: Pre-Fire NDVI for Kunda

- **Post-Fire NDVI (Green):**
  - In the Post-Fire NDVI image, the area around the point of interest turns green, indicating a noticeable increase in vegetation health or density. This change suggests a significant regrowth or recovery of vegetation post-fire, likely influenced by favorable climatic conditions in Kunda, such as high rainfall.

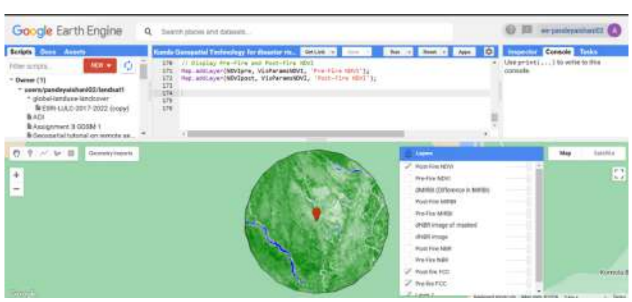


Figure 19: Post-Fire NDVI for Kunda

- **dNDVI (Red):**
  - The dNDVI image shows a red tone at the point of interest, representing a substantial decrease in NDVI values from pre- to post-fire. This indicates a negative change in vegetation density,

indicating that the region saw a decrease in vegetation health or density post-fire, meaning the fire had a lasting negative impact on vegetation in these areas.

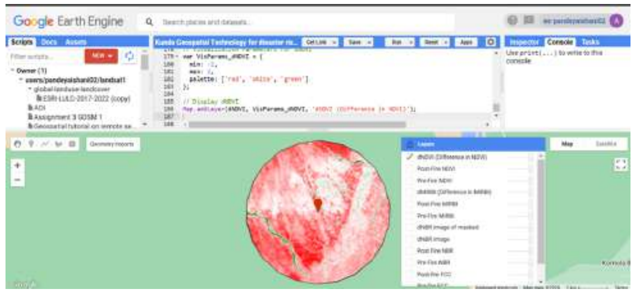


Figure 20: dNDVI for Kunda

The NDVI analysis reveals a strong vegetation recovery in Kunda post-fire, potentially due to high rainfall and suitable climate conditions that support regrowth.

7.1.5 Burn Area Index (BAI)

The Burn Area Index (BAI) is a valuable spectral index for identifying and assessing burned areas by analyzing reflectance in the red and near-infrared (NIR) bands. In areas like Kunda, BAI is particularly useful for tracking burn severity and **confirming potential regrowth after fire events**. By comparing pre- and post-fire BAI values, it is possible to evaluate the degree of burn impact and observe vegetation recovery. Kunda's climate, characterized by high rainfall, can facilitate rapid regrowth, which may be reflected in post-fire BAI analysis. This makes BAI an effective tool to verify the vegetation regrowth hypothesis in this region.

- **Low BAI Value**: Indicates minimal burn presence. In areas with low BAI, vegetation is likely unburned or healthy, with lower reflectance in the red and NIR bands. Low BAI values can also suggest moist soil or vegetation with high moisture content, as these surfaces tend to absorb more light.
- **High BAI Value**: Indicates a strong burn signal, often found in areas recently impacted by fire. High BAI values are associated with exposed soil, ash, and charred vegetation, which increase reflectance in the red and NIR bands.

dBAI (Difference in BAI) Values:

- **Low dBAI Value**: Suggests little to no change in burn presence between the pre- and post-fire periods. Low dBAI values imply stable conditions, either unburned or consistently burned, with minimal vegetation recovery or degradation.
- **High dBAI Value**: Indicates a significant change in burn status. A high positive dBAI value suggests an increase in burn presence, potentially due to new fires or intensification of burn severity. Negative dBAI values (if present in the color scale) would indicate recovery or regrowth in previously burned regions.

In our analysis, **White <Yellow <Orange <Red** represents the increasing order of BAI values and **Blue <White <Red** represent increasing order of dBAI values.

- Pre-Fire BAI (Orange)

  In Kunda, the Pre-Fire BAI image displays an orange color at the point of interest, suggesting a high initial burn presence or dry vegetation before the observed fire event. This initial high BAI value might result from residual impact from previous burns or existing vegetation stress in the dry season.

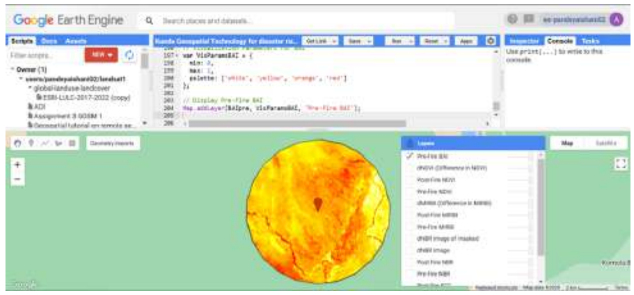


Figure 21: Pre-Fire BAI for Kunda

- Post-Fire BAI (Yellow)

  Post-Fire BAI shifts to yellow at the same point, suggesting a reduction in burn signature, likely due to rapid vegetation **regrowth** aided by Kunda's favorable climate and high rainfall. This change implies improved vegetation health and moisture retention, contrasting the pre-fire burn intensity.

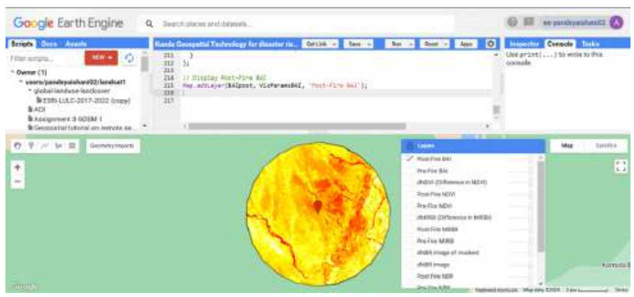


Figure 22: Post-Fire BAI for Kunda

- dBAI (White)

  The dBAI image shows a white color at the area of interest, indicating minimal change in burn presence. This result suggests a stable post-fire condition, either through effective regrowth or low burn severity. The color scale progression from 'blue' to 'white' to 'red' (for -0.5 to 0.5) suggests that dBAI remained consistent, highlighting Kunda's resilience and its potential for rapid vegetation recovery after fires.

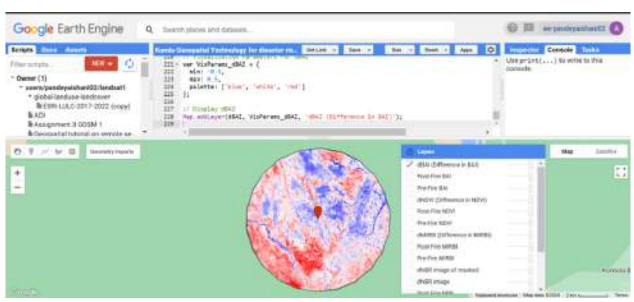


Figure 23: dBAI for Kunda

8 Effectiveness of NBR/dNBR for Kunda

8.1 Effectiveness Ranking

1. **Highest - MIRBI**: Ideal for severe burn assessment, highly sensitive to ash and exposed soil.

2. **Second - BAI**: Effectively captures burn presence by identifying increased reflectance in the red and NIR bands. It can detect burned regions well and track early regrowth, which is valuable in a high-rainfall region like Kunda, where regrowth is prominent.

3. **Third - NBR/dNBR**: Effective for delineating vegetation burn, particularly when vegetation health varies.

4. **Lowest - NDVI**: Reflects general vegetation health but lacks specificity for burn severity.

8.2 Conclusion

While NBR/dNBR serves as a primary tool for delineating burns in vegetation, MIRBI provides additional precision in assessing soil and ash exposure. This combination offers a comprehensive approach to fire impact analysis in areas with mixed vegetation, such as Kunda.

8.3 Near Dada, Uttarakhand (Western Himalayas)

8.3.1 False Color Composite (FCC)

- **Pre-Fire FCC (green)**:
  - In false color imagery, green tones typically indicate healthy vegetation due to the strong reflectance in the Near-Infrared (NIR) and absorption in the red bands.
  - Here, the green color in the pre-fire FCC suggests a well-vegetated, healthy area with minimal disturbance.

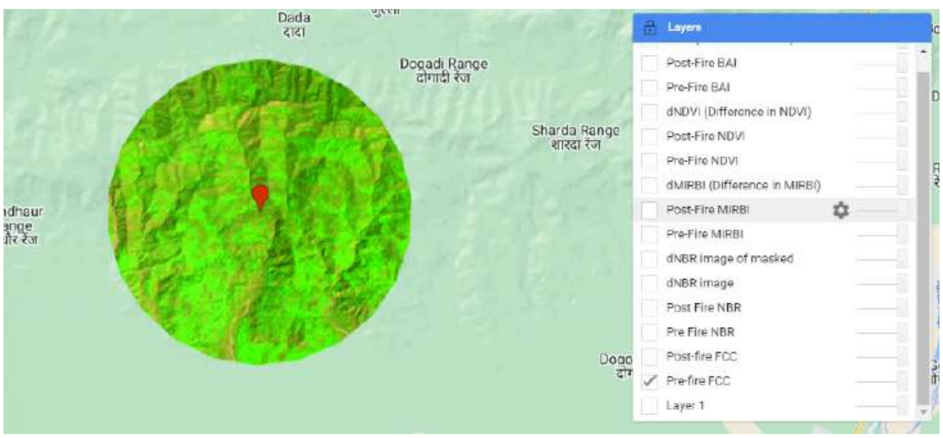


Figure 24: Pre fire FCC

- **Post-Fire FCC (mustard/yellow)**:
  - The shift from green to mustard or yellow indicates vegetation loss or alteration in surface composition. This is common after a fire, as vegetation is burned, and the landscape reflects more in the red and SWIR bands, which represent soil or charred ground.
  - The yellow tones likely reflect the reduced chlorophyll and the exposed ground, a sign of post-fire impact.

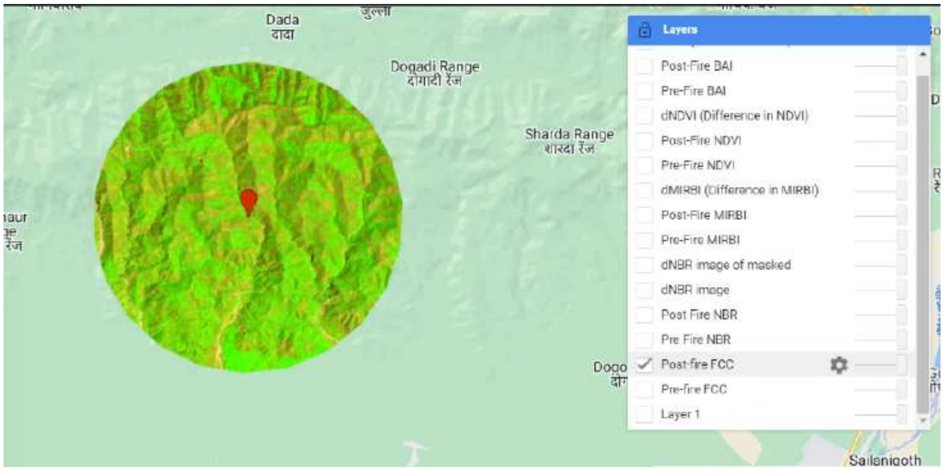


Figure 25: Post fire FCC

8.3.2 Normalized Burn Ratio (NBR)

- **Pre-Fire NBR (grey)**:
  - NBR measures vegetation health, with higher values typically indicating healthy, dense vegetation (reflected in darker colors).
  - Grey tones in the pre-fire NBR image suggest moderately healthy vegetation, which corresponds to undisturbed areas, though not with extremely dense canopy cover.

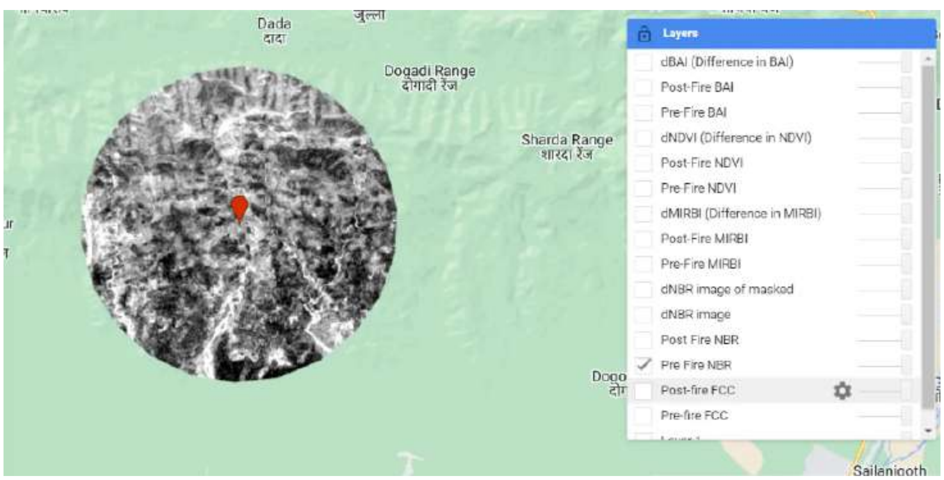


Figure 26: Pre fire NBR

- **Post-Fire NBR (dark grey)**:
  - The shift to darker grey after the fire reflects a decrease in vegetation health or density. Fires reduce the vegetation's NIR reflectance due to the loss of biomass and increased reflectance in the SWIR bands, which is associated with exposed or charred ground.
  - This color change in NBR is a clear indicator of burned or degraded vegetation.

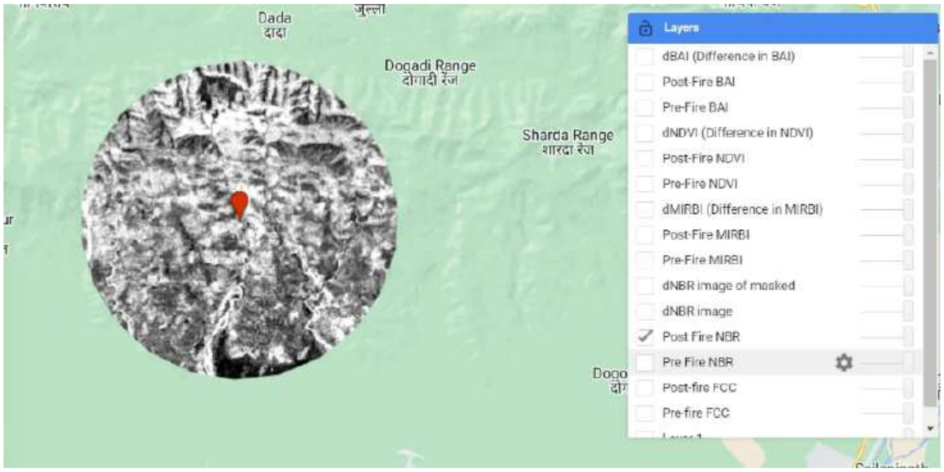
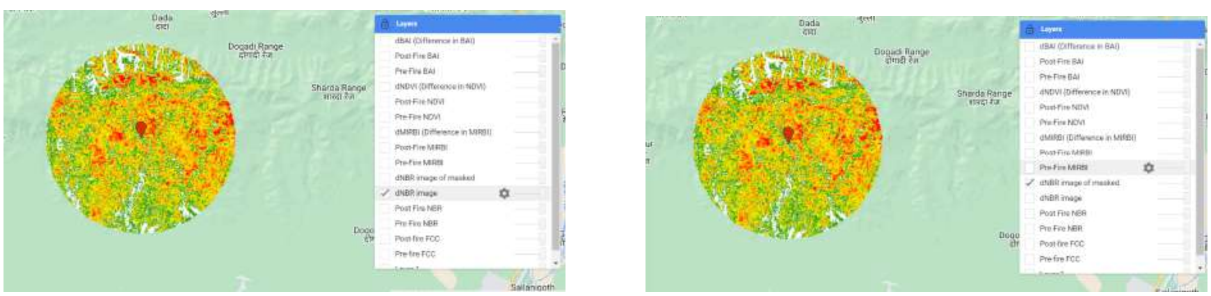


Figure 27: Post fire NBR

- **dNBR (yellow in unmasked and masked)**:
  - dNBR is the difference between pre- and post-fire NBR values, with values closer to yellow in your palette often representing lower burn severity or areas with minimal vegetation loss.
  - The yellow here suggests the fire may have had low-to-moderate severity in these regions, causing partial damage without complete destruction of vegetation.



(a) dNBR

(b) dNBR Masked

8.3.3 Mid-Infrared Burn Index (MIRBI)

- **Pre-Fire MIRBI (yellow)**:
  - MIRBI is specifically designed to detect burned areas using SWIR bands. In the pre-fire image, the yellow indicates a lower baseline of burn intensity, likely representing unburned or healthy areas.

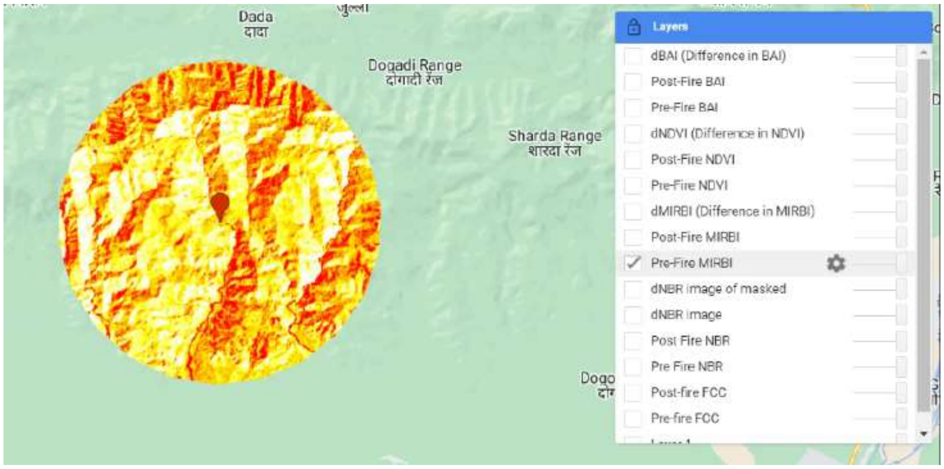


Figure 29: Pre fire MIRBI

- **Post-Fire MIRBI (darker yellow/orangish)**:
  - The darker yellow and orange tones suggest an increase in MIRBI values, which aligns with fire impacts on the vegetation. Post-fire, the land reflects more SWIR due to the absence of vegetation and the presence of charred material or bare soil.
  - This shift is a marker of the landscape's altered reflectance characteristics after the fire event.

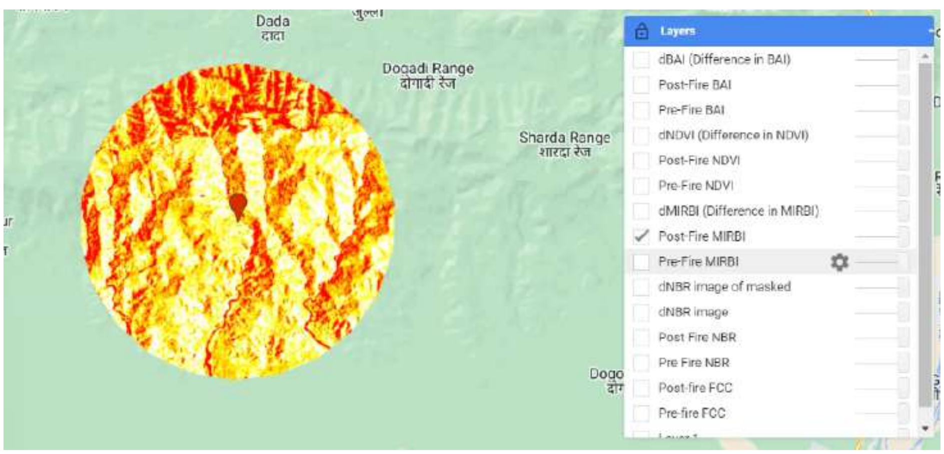


Figure 30: Post fire MIRBI

- **dMIRBI (orange)**:
  - Higher values of dMIRBI in orange highlight areas of significant change in the MIRBI index, pointing to locations with substantial fire impact and vegetation alteration.
  - The orange dMIRBI in the output indicates a moderate-to-high burn severity, with extensive surface alteration due to fire.

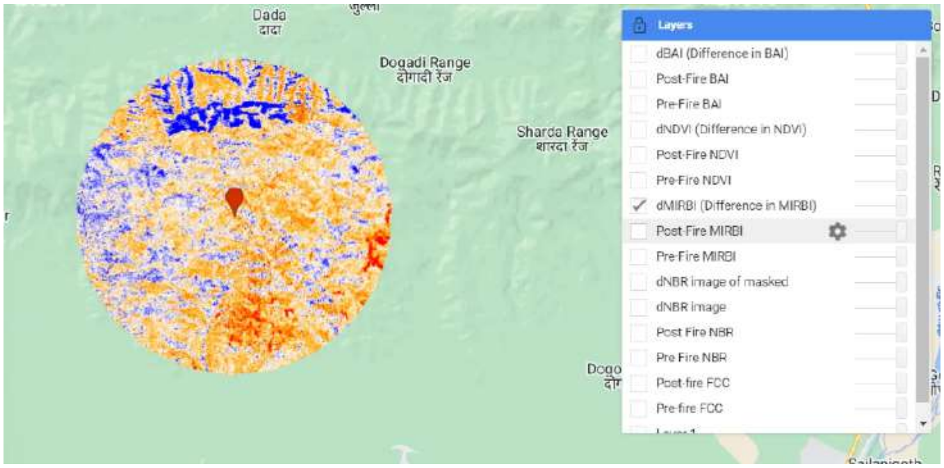


Figure 31: dMIRBI

8.3.4 Normalized Difference Vegetation Index (NDVI)

- **Pre-Fire NDVI (sage green)**:
  - NDVI measures the health and density of vegetation, with higher values indicating lush vegetation. Sage green represents moderate NDVI values, corresponding to an area with a healthy but possibly moderate-density canopy cover.

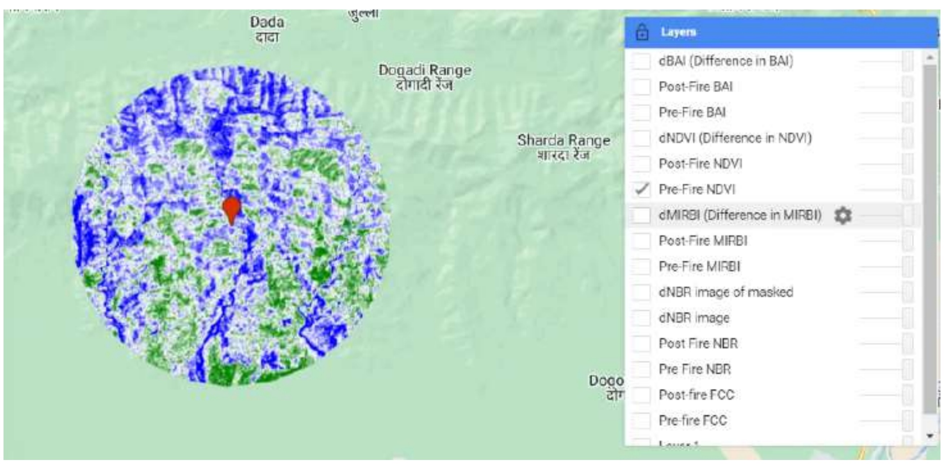


Figure 32: Pre fire NDVI

- **Post-Fire NDVI (lighter green)**:
  - After a fire, NDVI values generally decrease as vegetation is lost or damaged. The lighter green color in the post-fire NDVI indicates a decline in vegetation density or health, likely due to reduced photosynthetic activity in remaining vegetation.
  - This reduction in NDVI is a common sign of fire impact, showing the altered vegetation structure and health.

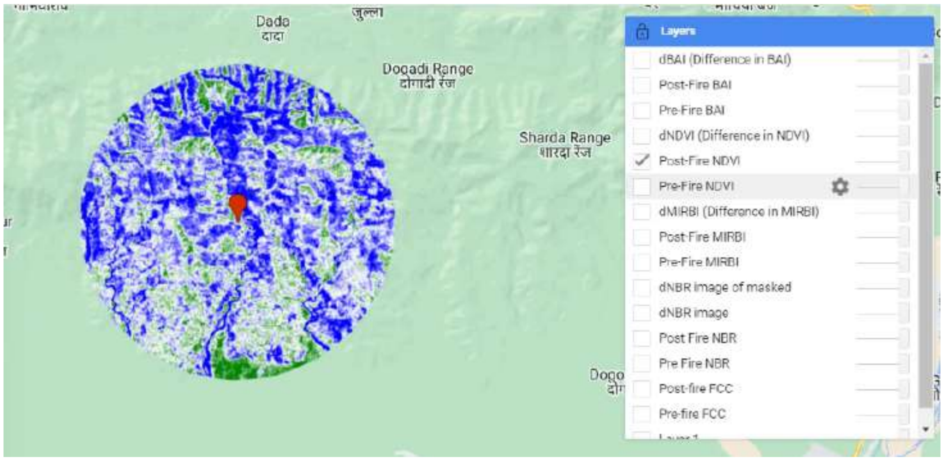


Figure 33: Post fire NDVI

- **dNDVI (tones of red)**:
  - Red in dNDVI acts as a good indicator of burn severity. The more intense the red, the greater the loss of vegetation, which can help differentiate between areas with varying levels of fire damage.
  - A high dNDVI drop (red) suggests severe fire impact, as healthy vegetation (high NDVI) has transitioned to low or no vegetation cover (low NDVI).

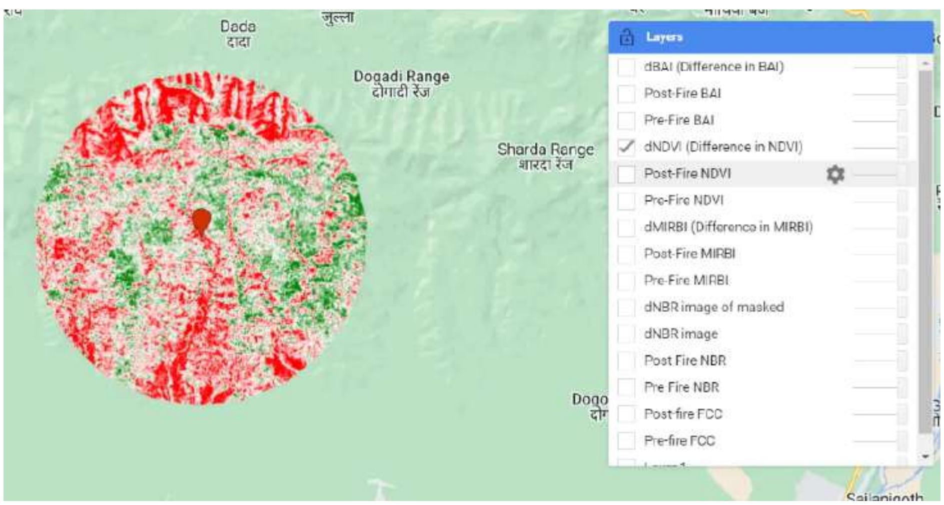


Figure 34: dNDVI

8.3.5 Burned Area Index (BAI)

- **Pre-Fire BAI (orange)**:
  - BAI detects recently burned areas, with higher values often indicating recent fire presence. Dark orange tones here represent a low baseline BAI, meaning the area was undisturbed before the fire event.

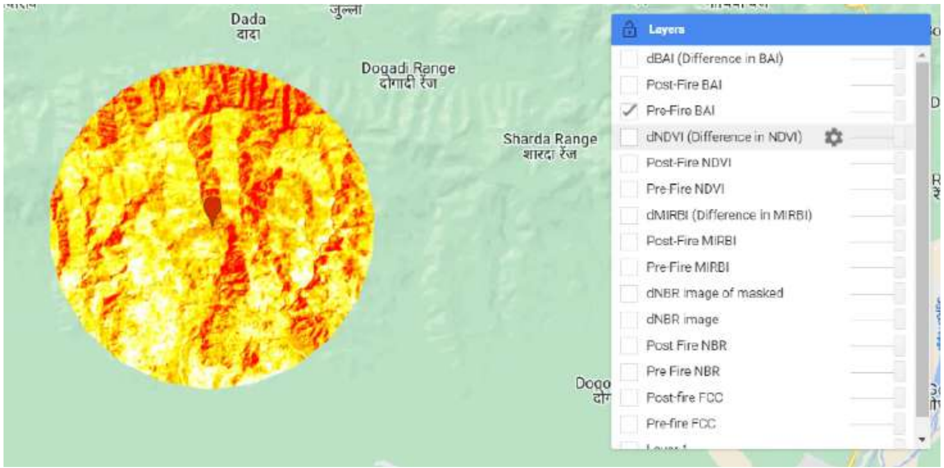


Figure 35: Pre fire BAI

- **Post-Fire BAI (darker shades of orange/yellow)**:
  - BAI typically increases in burned areas because the charred remains and ash absorb more near-infrared and red light, resulting in these darker, more intense shades in the BAI color palette.
  - This tonal shift can thus highlight the fire's severity or the extent of burning in the area, as darker oranges and yellows often correlate with regions experiencing a more intense burn effect.

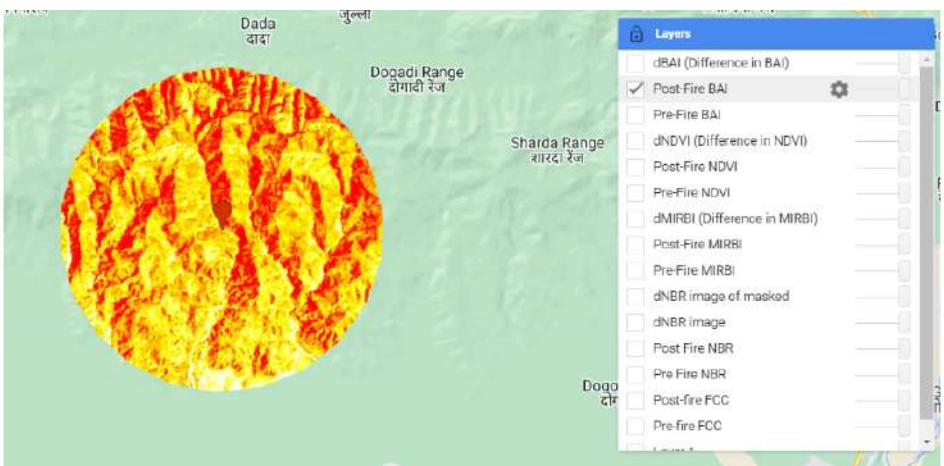


Figure 36: Post fire BAI

- **dBAI (light red)**:
  - The color shift to light red in the dBAI difference image signals a reduction in burned area index post-fire, likely due to early signs of regeneration or a lower-intensity fire.
  - This suggests the fire may not have left long-lasting burn scars or that some areas are beginning to recover, leading to reduced BAI values.

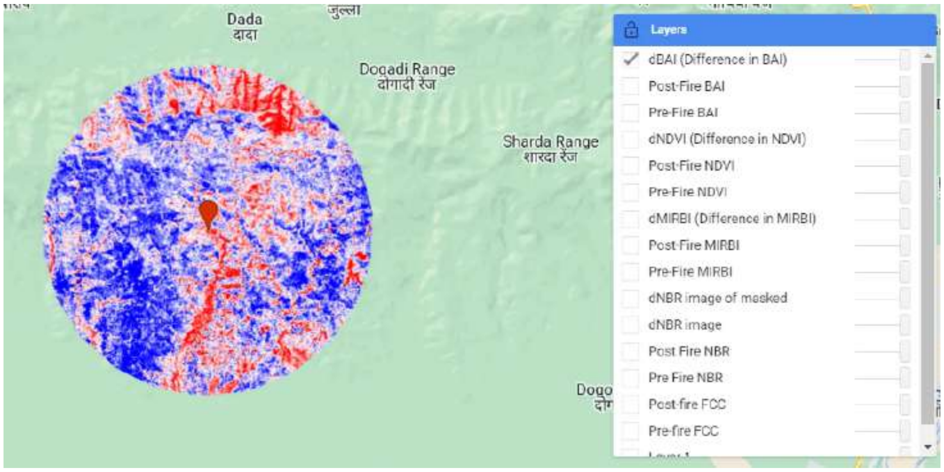


Figure 37: dBAI

8.4 Shiroli, Karnataka (Western Ghats)

8.4.1 False Color Composite (FCC)

The False Color Composite (FCC) images provide a visual representation of vegetation health and land cover by using different spectral bands, typically Near-Infrared (NIR), Red, and Green, to highlight vegetation and burned areas. FCC is particularly effective for observing vegetation differences before and after fire events.

- **Pre-Fire FCC (Green):**
  - The pre-fire FCC image at Shiroli shows a dominant green color, indicating healthy, dense vegetation around the area of interest. This suggests that the region was well-vegetated and likely moist before the fire, with substantial plant cover.

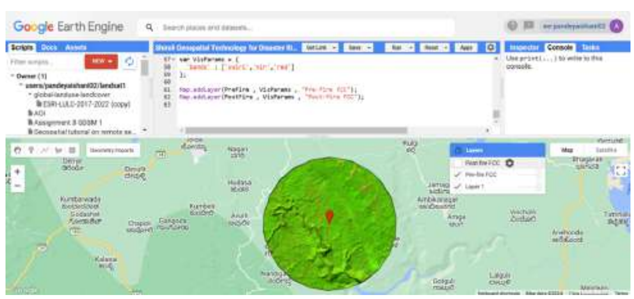


Figure 38: Pre-Fire FCC for Shiroli

- **Post-Fire FCC (Grey):**
  - Post-fire FCC reveals a shift to grey, indicating reduced vegetation. This color change suggests significant vegetation loss due to the fire, with previously green areas now showing bare or lightly vegetated soil.

The FCC analysis reveals substantial vegetation damage in Shiroli post-fire, with healthy vegetation replaced by bare or sparse land cover, as indicated by the transition from green to grey.

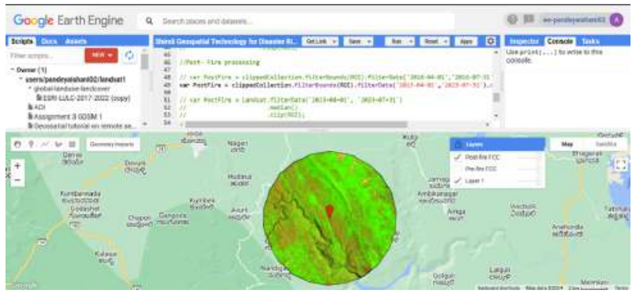


Figure 39: Post-Fire FCC of Shiroli

8.4.2 Normalized Burn Ratio (NBR)

The **Normalized Burn Ratio (NBR)** is used to identify burned areas and vegetation health by analyzing the Near-Infrared (NIR) and Shortwave Infrared (SWIR) bands. High NBR values indicate healthy vegetation, while low NBR values suggest vegetation loss or burn presence.

- **Pre-Fire NBR (Black):**
  - The pre-fire NBR image at Shiroli shows a dark grey to black color, indicating relatively high NBR values that correspond to healthy vegetation cover or moisture-rich areas before the fire.

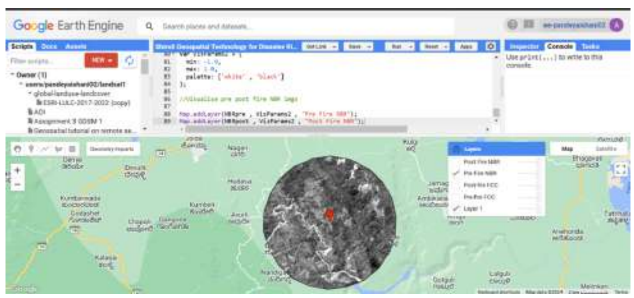


Figure 40: Pre-Fire NBR for Shiroli

- **Post-Fire NBR (White):**
  - The post-fire NBR image shows a transition to white, representing a low NBR value and a marked reduction in vegetation health, likely due to fire damage.

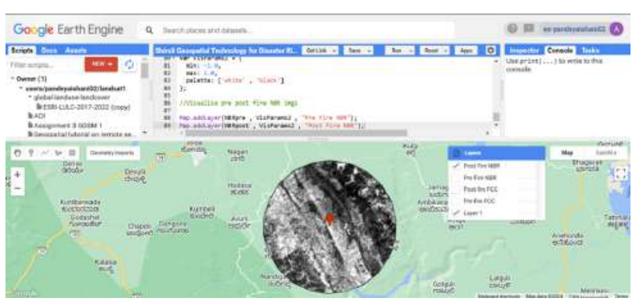


Figure 41: Post-Fire Shiroli

- **dNBR (Orange):**

- The orange tone in the dNBR image suggests moderate burn severity, indicating vegetation loss but not complete devastation.

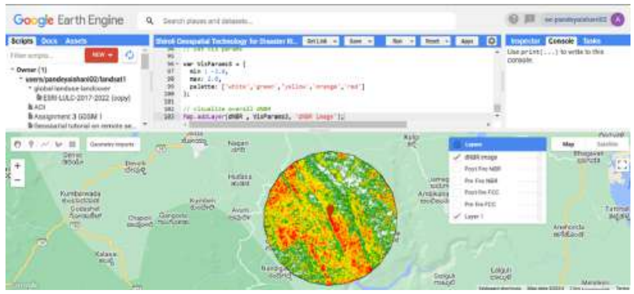


Figure 42: dNBR for Shiroli

- **Masked dNBR (Red):**
  - After masking water bodies, the dNBR image shows red, suggesting high burn severity. This indicates areas where vegetation loss due to fire is particularly intense.

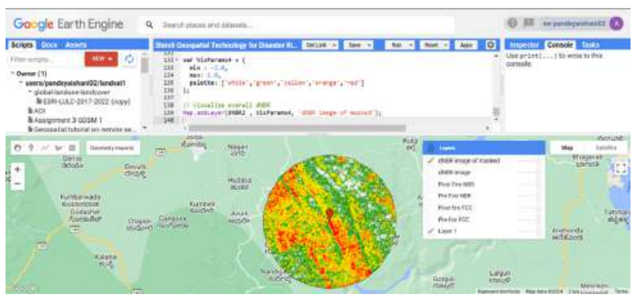


Figure 43: Masked dNBR for Shiroli

8.4.3 Mid-Infrared Burn Index (MIRBI)

The **Mid-Infrared Burn Index (MIRBI)** uses SWIR bands to detect burned surfaces, especially ash and char, which exhibit high reflectance in these wavelengths. MIRBI is calculated using a combination of SWIR1 and SWIR2 bands, with higher values indicating greater burn severity.

- **Pre-Fire MIRBI (Yellow):**
  - The pre-fire MIRBI value at Shiroli is yellow, indicating moderate burn susceptibility or drier conditions, which might increase the area's fire risk.

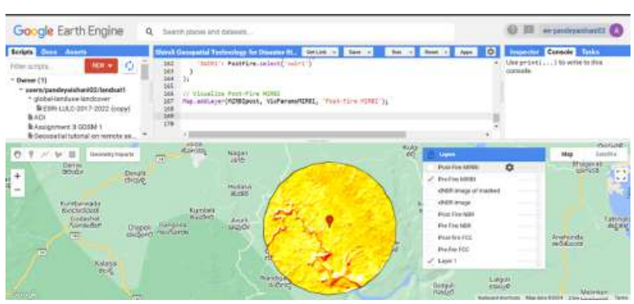


Figure 44: Pre-Fire MIRBI for Shiroli

- **Post-Fire MIRBI (Yellow):**
  - Post-fire MIRBI remains yellow, indicating that while the vegetation may have been affected, the burn impact has not drastically increased surface dryness or ash exposure.

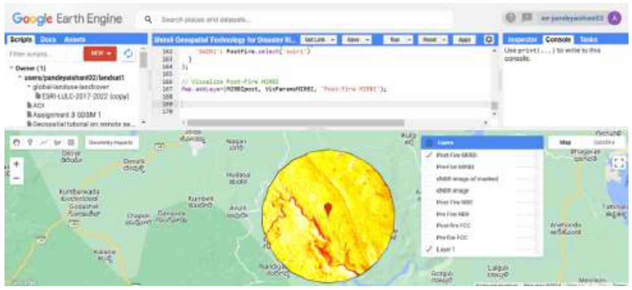


Figure 45: Post-Fire MIRBI for Shiroli

- **dMIRBI (Orange):**
  - The dMIRBI image shows orange, indicating moderate change in burn severity, with some increase in ash or char exposure following the fire.

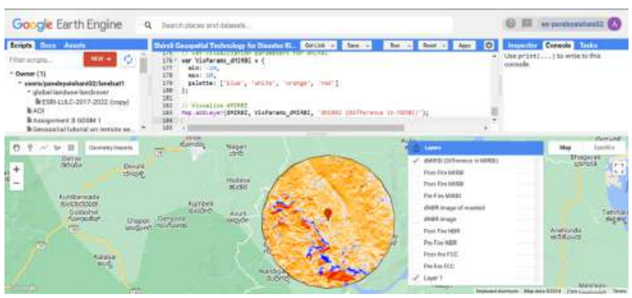


Figure 46: dMIRBI for Shiroli

8.4.4 Normalized Difference Vegetation Index (NDVI)

The **Normalized Difference Vegetation Index (NDVI)** is a measure of vegetation health. High NDVI values indicate healthy vegetation, while low values suggest sparse or damaged vegetation.

- **Pre-Fire NDVI (Light Green):**
  - The pre-fire NDVI shows light green, indicating moderate vegetation health, though not fully dense or healthy.

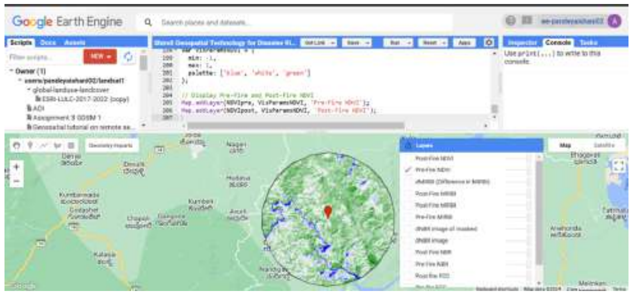


Figure 47: Pre-Fire NDVI for Shiroli

- **Post-Fire NDVI (Blue):**
  - Post-fire NDVI turns blue, indicating low vegetation health, likely resulting from fire damage, with vegetation significantly affected or sparse.

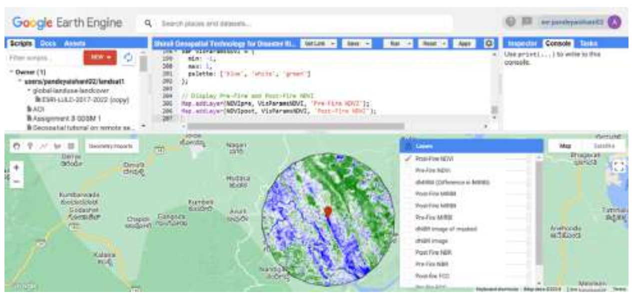


Figure 48: Post-Fire NDVI for Shiroli

- **dNDVI (Green):**
  - dNDVI shows green, indicating a substantial positive change post-fire, possibly due to natural recovery in certain regions.

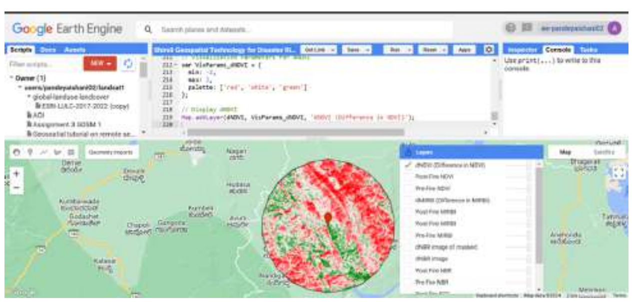


Figure 49: dNDVI for Shiroli

8.4.5 Burn Area Index (BAI)

The **Burn Area Index (BAI)** focuses on detecting burned areas by measuring reflectance in the red and NIR bands. Higher BAI values indicate burn presence or bare soil, while lower values represent healthy vegetation or moist soil.

- **Pre-Fire BAI (Yellow):**

– Pre-fire BAI at Shiroli is yellow, suggesting moderate vegetation and soil dryness, increasing the area's susceptibility to fire.

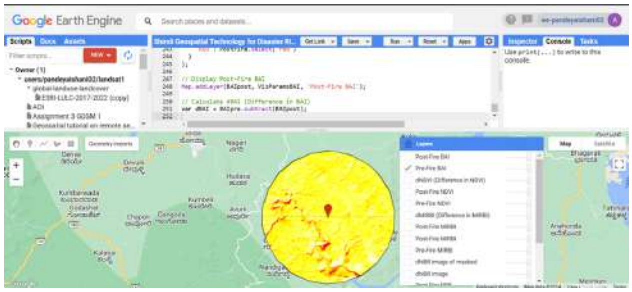


Figure 50: Pre-Fire BAI for Shiroli

- **Post-Fire BAI (Yellow):**
  – Post-fire BAI also remains yellow, indicating that the burn impact did not drastically alter the surface reflectance, suggesting limited burn severity.

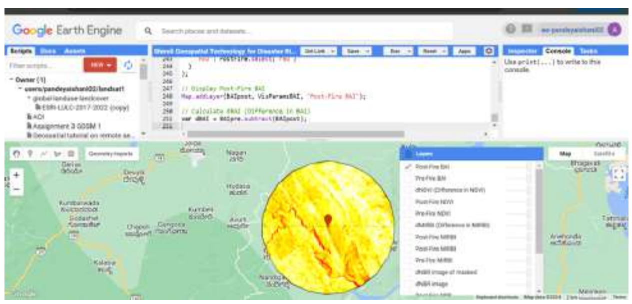


Figure 51: Post-Fire BAI for Shiroli

- **dBAI (Blue):**
  – The dBAI image shows blue, indicating minimal change in burn status, with no significant vegetation recovery or additional degradation.

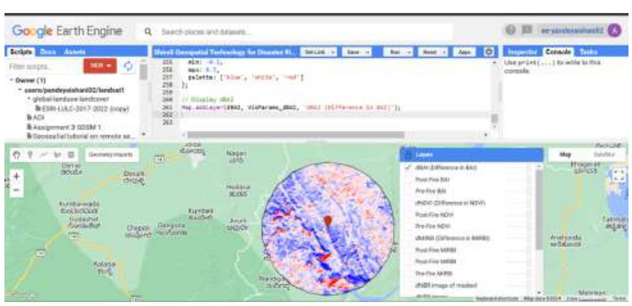


Figure 52: dBAI for Shiroli

9 Evaluation of NBR/dNBR Effectiveness

9.1 Effectiveness of NBR/dNBR

- **NBR**: Distinguishes healthy vs. burned vegetation.

- **dNBR**: Highlights burn severity effectively, with orange and red tones showing moderate-to-high impact areas.

9.2 Comparison with Other Indices

- **MIRBI**: Detects ash and char well but is less sensitive to subtle vegetation changes.
- **NDVI**: Useful for assessing general vegetation health but lacks precision for burn severity analysis.
- **BAI**: Effectively detects burned areas but is less suitable for post-fire recovery analysis.

9.3 General Effectiveness Ranking (Increasing Order)

1. **BAI** - Limited in sensitivity to post-fire vegetation changes.
2. **NDVI** - Lacks specificity in assessing burn severity.
3. **MIRBI** - Suitable for burn detection but misses finer vegetation changes.
4. **NBR/dNBR** - Most effective for differentiating burn severity and monitoring vegetation recovery.