CE671A Lab 5

Aadya Umrao
210003
Civil Engineering
aadyau21@iitk.ac.in

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1 Introduction

The objective of this lab is to analyze the changes in vegetation cover over time for a specific region of interest, using Google Earth Engine. The primary method involves calculating the Normalized Difference Vegetation Index (NDVI) over a given period to understand how vegetation in the region has varied. The ultimate goal is to create a graph, similar to the one provided, which visually represents the fluctuations in vegetation cover based on NDVI values. The exercise requires performing this analysis using Landsat 8 data for a region of interest and optionally comparing the results with similar analysis done using MODIS data. By comparing the outputs of these two datasets over the same time period and region, one can gain a deeper understanding of the vegetation dynamics and the effectiveness of different satellite data sources. The exercise also prompts exploration of other vegetation indices (VI) that can provide insights into vegetation health, each with its specific significance.

2 Methodology

2.1 Procedure-

Selecting the Region of Interest (ROI):

- The region of interest was defined around Lucknow, India. This region was selected for analyzing vegetation cover changes using satellite data.

Importing the Satellite Data:

- Landsat 8 Data: The `LANDSAT/LC08/C02/T1_TOA` dataset was used. This dataset provides Top of Atmosphere (TOA) reflectance data, which is essential for calculating NDVI.
- MODIS Data: For comparative analysis, the MODIS dataset can be imported, which provides higher temporal resolution but lower spatial resolution compared to Landsat 8.

Data Preprocessing

1. Cloud Masking:

- Cloud masking was applied to remove any pixels affected by clouds or cloud shadows, ensuring that only clear-sky observations were used in the NDVI calculation. This was crucial for accurate vegetation analysis.

2. Filtering the Data:

- The satellite data was filtered based on the date range of interest, typically spanning several years (e.g., 2014-2024) to observe long-term vegetation trends.
- The data was further filtered to include only images captured during the month of January each year, providing a consistent temporal dataset for analysis.

NDVI Calculation

Formula Application:

- The NDVI was calculated using the formula:

$$\text{NDVI} = \frac{NIR - RED}{NIR + RED}$$

where NIR and RED represent the near-infrared and red bands, respectively, from the satellite imagery.

Applying the NDVI Calculation:

- The NDVI calculation was applied to each filtered image within the dataset, generating a time series of NDVI values for the region of interest.

Time Series Chart Creation:

- A time series chart was created to visualize the NDVI values over time, specifically plotting NDVI against the date for each January from 2014 to 2024.
- This chart allowed for the identification of trends and patterns in vegetation cover within the Lucknow region.

Comparative Analysis

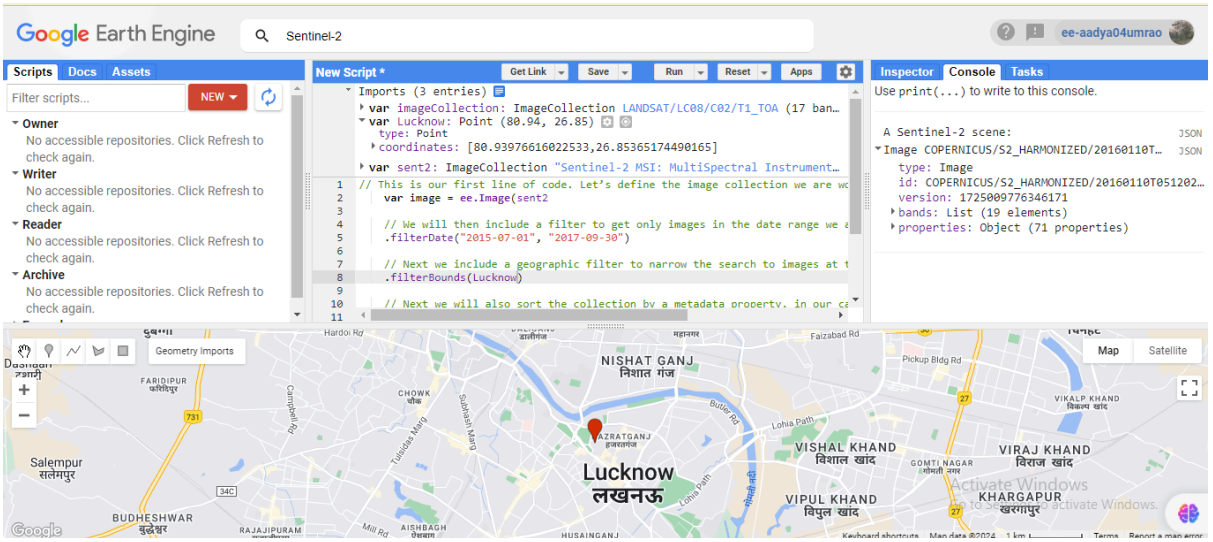
Performing Similar Analysis with MODIS Data:

- If desired, a similar NDVI analysis was conducted using MODIS data for the same region and time period.
- The results from Landsat 8 and MODIS were compared to assess the consistency and differences between the two datasets.

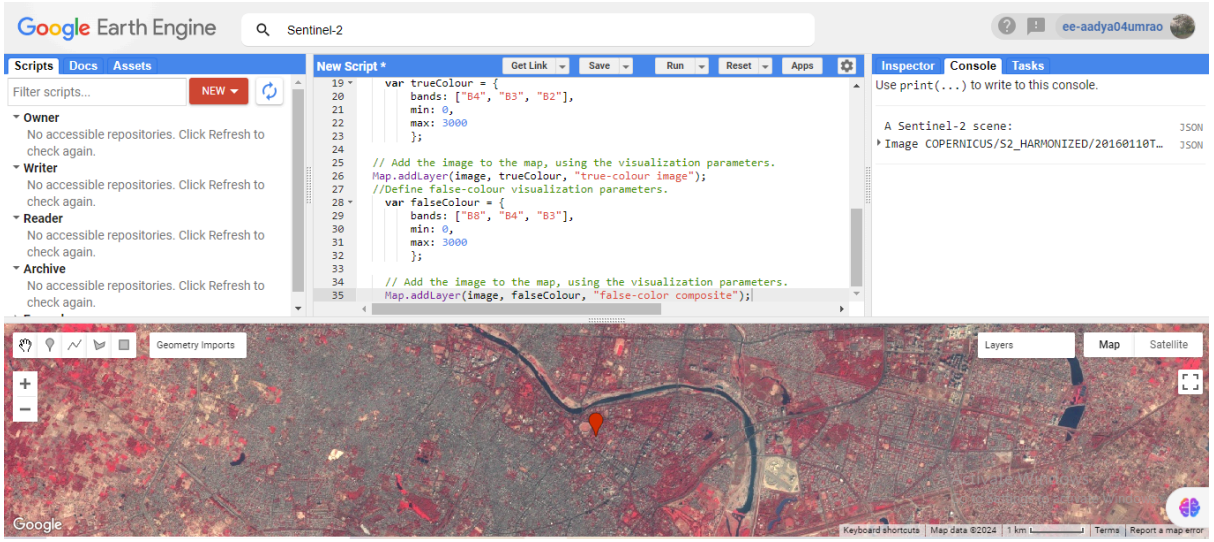
2.2 Results-

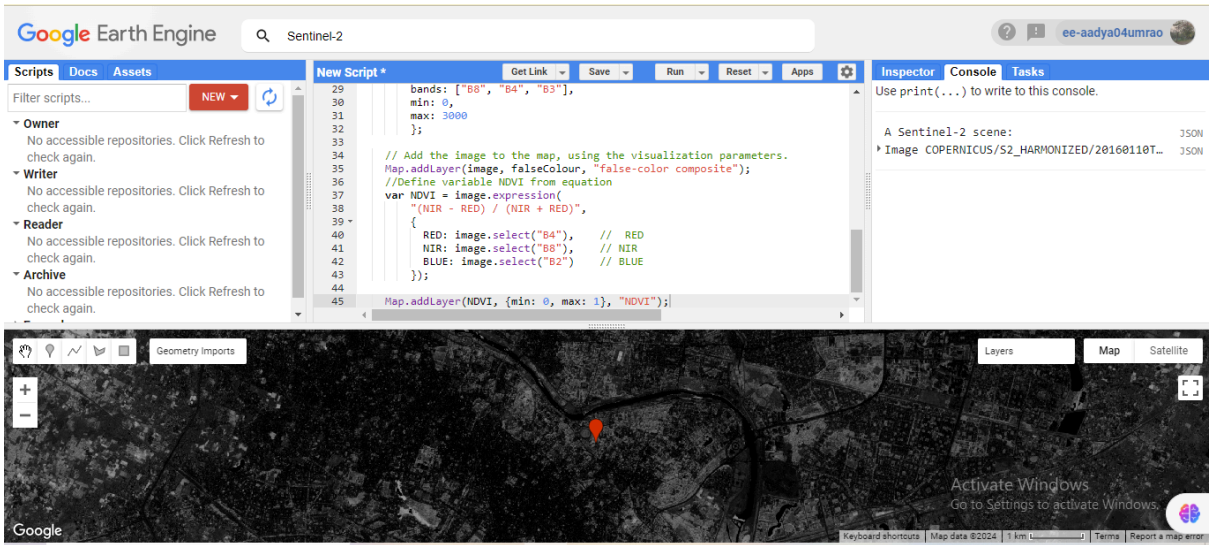
1) Using Google Earth Engine for LANDSAT8 data-

- Importing the required data and Specifying region of interest as Lucknow-

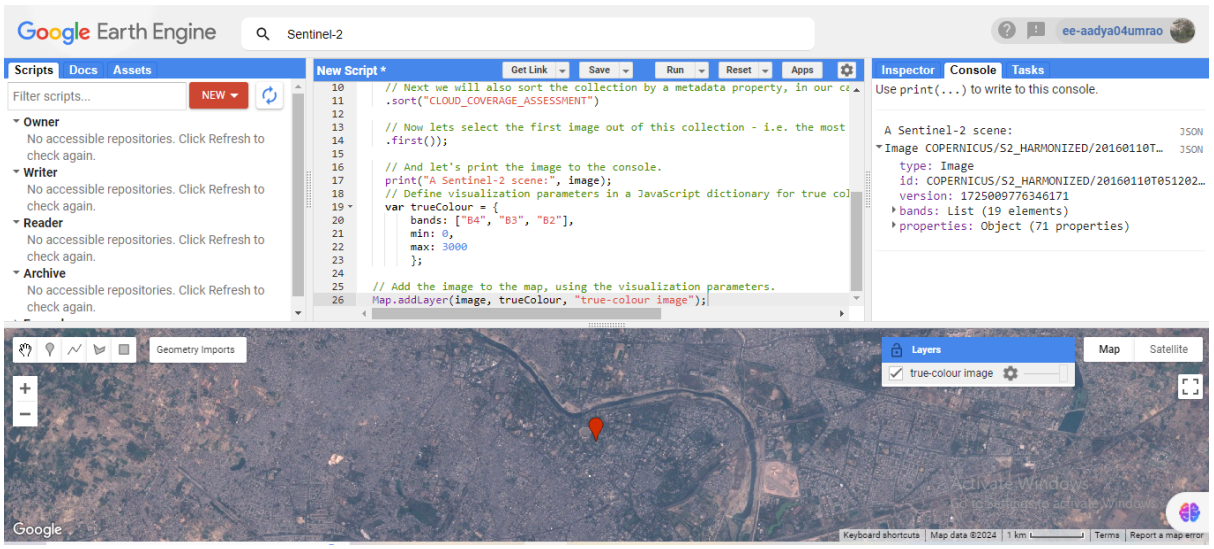


- Trying to apply geographic filters and obtain the most cloud free image-

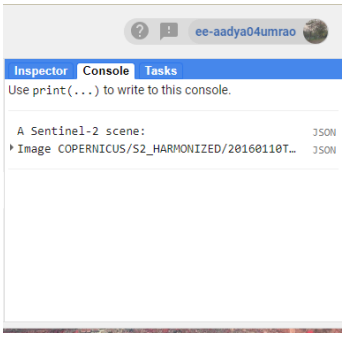




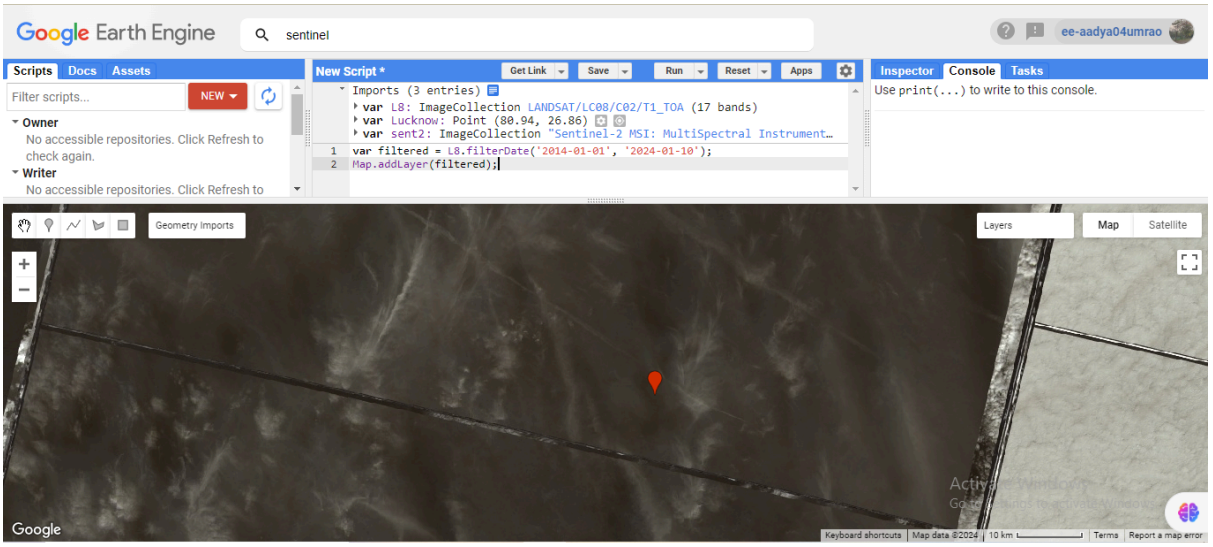
- Exploring options like Layer, Geometry, etc. on Map



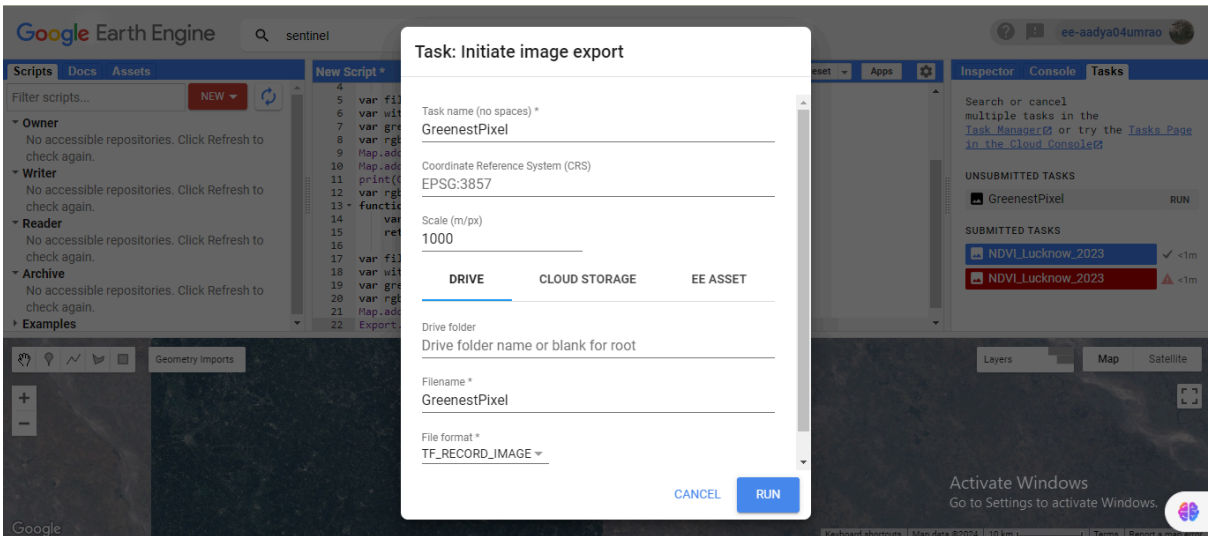
- A snapshot of what console tab prints.

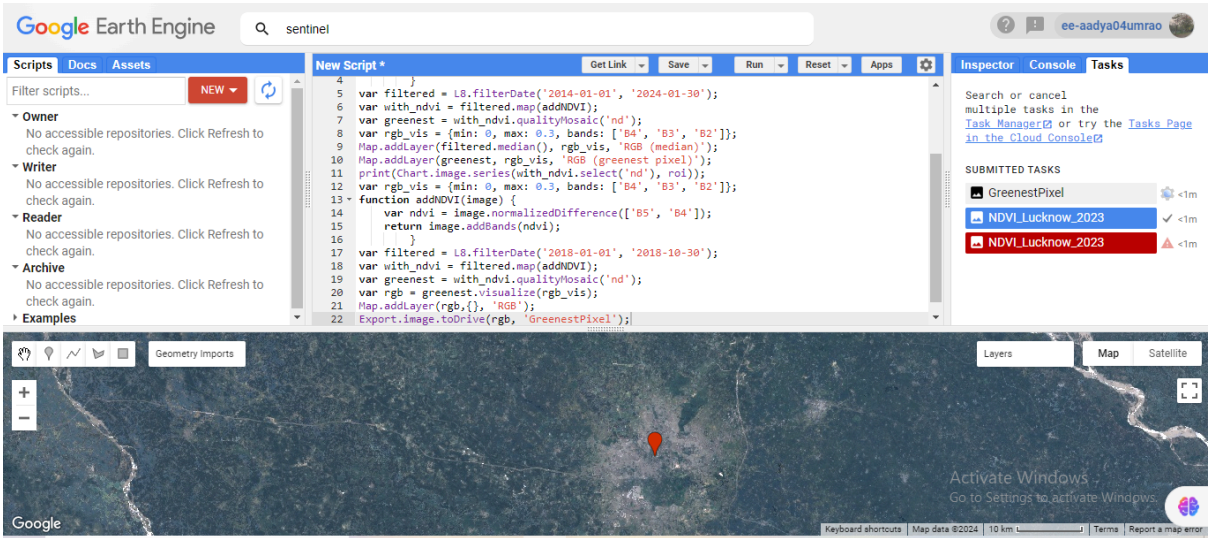


- Applying filters on area of interest

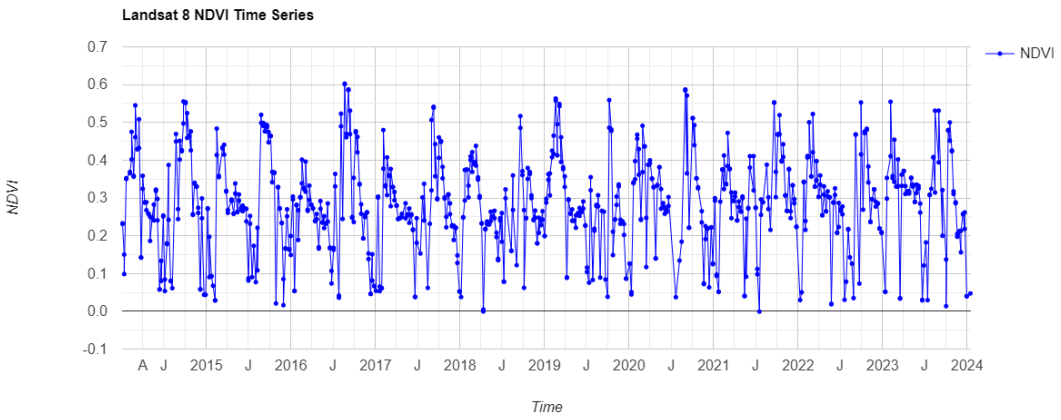


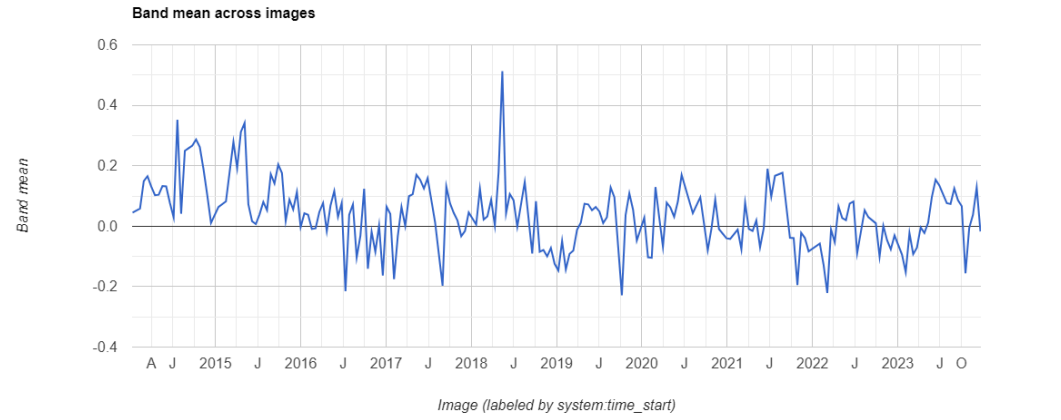
- Exporting the image obtained using Task tab in Geotiff/Image format to Google drive.





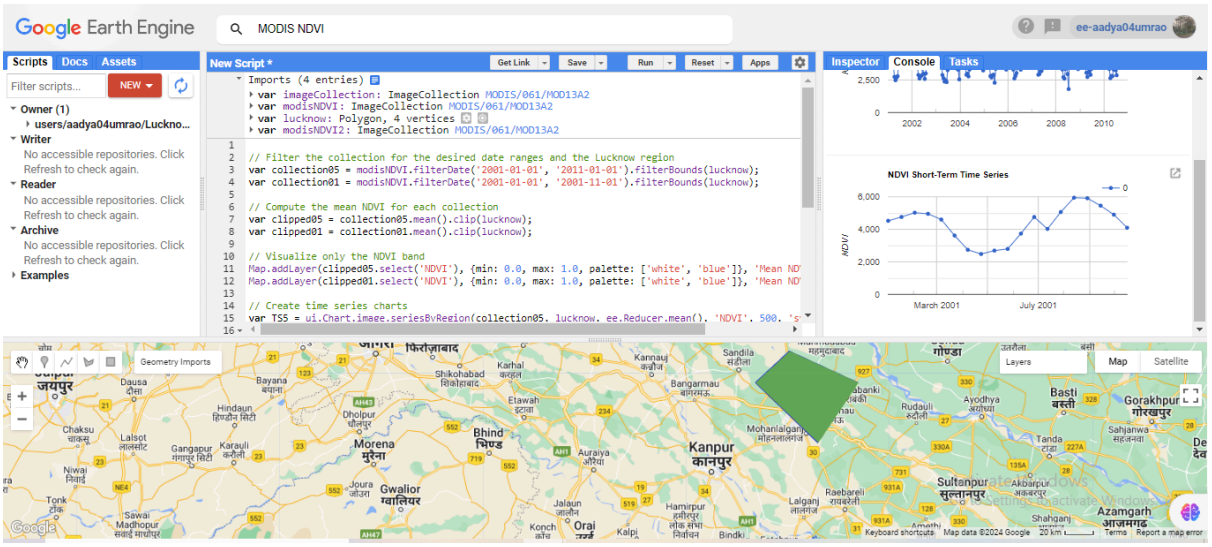
OBTAINED PLOT FOR LUCKNOW REGION for 10 years(2014-2024) for LANDSAT8 data-



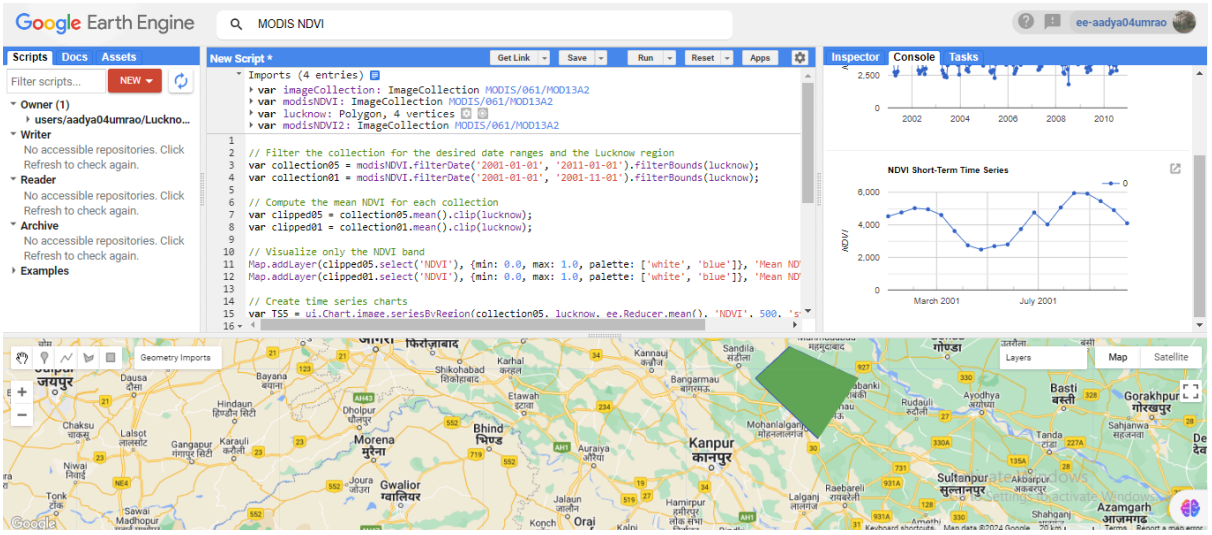


2) Using MODIS data to draw similar inferences-

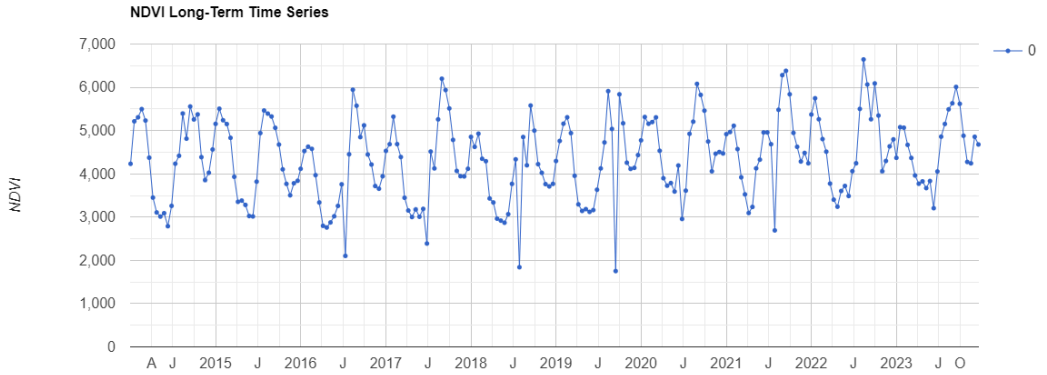
- Importing required dataset and setting roi(region of interest) as Lucknow.

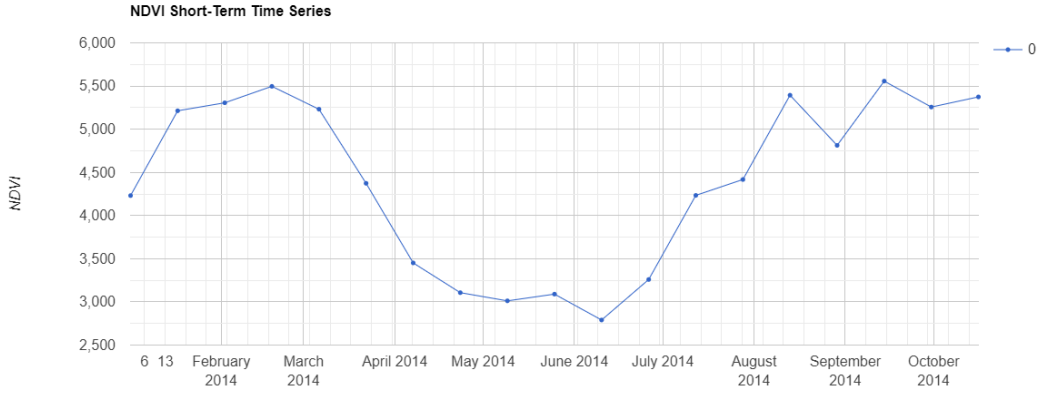


- Obtaining graph on Console tab

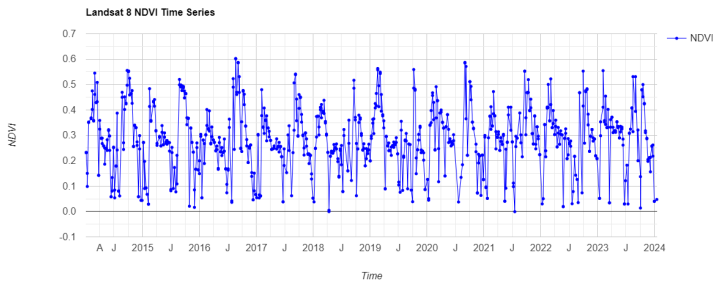


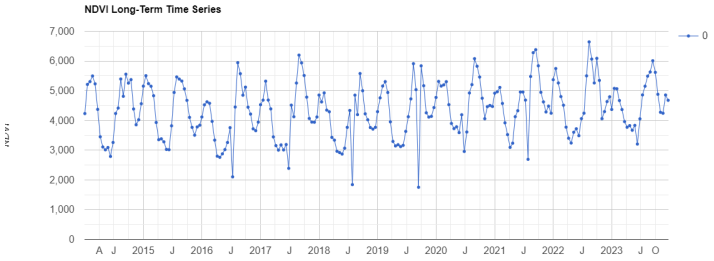
OBTAINED PLOT FOR **LUCKNOW** REGION for 10 years(2001-2010) for MODIS data-





COMPARISON OF OUTPUTS OBTAINED FROM BOTH LANDSAT8 and MODIS data for same span(2014-2024)-





The two charts represent NDVI (NormalizedDifference Vegetation Index) time series data for the Lucknow region from 2014 to 2024 using MODIS and Landsat 8 data, respectively.

Data Source and Resolution:

MODIS Data:

- Resolution: Coarser spatial resolution, typically around 250m to 1km.
- Sampling Frequency: Higher temporal resolution, often with daily or 16-day composites.
-Data Characteristics:This chart shows less variability in NDVI values, likely due to the broader spatial averaging inherent in MODIS data. Peaks and troughs are smoother and less extreme.

Landsat 8 Data :
- Resolution:Higher spatial resolution, typically around 30m.
- Sampling Frequency: Lower temporal resolution, with data typically available every 16 days.
- Data Characteristics:The chart exhibits more pronounced peaks and troughs in NDVI values, reflecting the higher spatial resolution and greater sensitivity to localized changes in vegetation cover.

NDVI Value Ranges:
- MODIS Data: NDVI values range approximately from 3000 to 6000 (likely scaled for the analysis), indicating a broader and more generalized measure of vegetation health.
- Landsat 8 Data: NDVI values range from about -0.1 to 0.6, showing a finer scale of NDVI measurements that can capture smaller changes in vegetation cover.

Temporal Patterns:
- MODIS Data: The trend is relatively stable over time, with periodic fluctuations likely corresponding to seasonal changes. However, the chart shows a somewhat smoother pattern due to the coarser spatial resolution.
- Landsat 8 Data: This chart displays more variability, with sharper and more frequent peaks and troughs. This could be due to the higher spatial resolution of Landsat data, which is more sensitive to localized changes in vegetation.

Outliers and Anomalies:
- MODIS Data: There are a few noticeable drops, especially around 2015 and 2020, indicating potential anomalies or periods of reduced vegetation.
- Landsat 8 Data: The Landsat 8 chart shows more frequent and pronounced drops in NDVI, which could indicate specific events like droughts, floods, or land-use changes that affected vegetation more locally.

Seasonal Variation:
- MODIS Data: Shows clearer seasonal cycles with consistent peaks and troughs, suggesting a more averaged and generalized view of vegetation over a larger area.
- Landsat 8 Data: Seasonal variation is also present but appears more irregular, reflecting the finer spatial resolution and the ability to detect localized changes.

Conclusion-
- MODIS Data: Provides a broad overview with smoother NDVI trends, useful for understanding regional or global vegetation patterns over time.
- Landsat 8 Data: Offers more detailed and localized information with sharper fluctuations in NDVI, making it better for assessing specific areas or detecting finer changes in vegetation cover.

Questions-

1) The obtained chart represents Band mean across images for the Lucknow region using the Landsat 8 dataset in Google Earth Engine. The *x-axis* represents time, labeled by the `system:time_start` parameter, while the *y-axis* shows the Band mean values.

Time Series:

- The x-axis ranges from January 2014 to January 2024, showing a monthly time series. Each data point represents the mean value of the specified band (likely NDVI) for the Lucknow region for that specific month.

Fluctuations in Band Mean:

- The y-axis represents the mean value of the band, which is likely an NDVI or a similar index.
- Positive values indicate greener or healthier vegetation, while negative values suggest lower vegetation health or areas with less vegetation.

Trends:

- 2014-2016: The values start positive, with some variability, indicating healthy vegetation during these years.
- 2016-2018: There is a noticeable decrease in the mean values, with some significant dips below zero. This could suggest a period of stress or reduction in vegetation, possibly due to climatic events, human activities, or seasonal variations.
- 2018: A sharp spike in 2018 may indicate a period of recovery or a specific event that led to a temporary increase in vegetation health.
- 2019-2024: The data shows more frequent fluctuations with some recovery periods, but also more frequent dips, indicating varying vegetation health or environmental conditions over these years. Possible reasons of not a fixed trajectory in this region could be COVID-19.

Seasonal Patterns:

- If the band represents NDVI, the fluctuations could be tied to seasonal changes in vegetation. Higher values could correspond to the monsoon season when vegetation is lush, while lower values could correspond to dry seasons.

Recent Trends:

- The recent data points from 2022 to 2024 show a mix of recoveries and dips, possibly indicating alternating periods of growth and stress in vegetation.

Conclusion:

The chart reflects the overall health and changes in vegetation over time in the Lucknow region, as captured by the Landsat 8 dataset. It highlights both seasonal variations and potential long-term trends in vegetation health, with notable periods of decline and recovery.

2)

Normalized Difference Vegetation Index (NDVI) is a widely used remote sensing index that measures the presence and condition of vegetation. It's a simple, yet powerful, indicator derived from satellite imagery, particularly useful for monitoring vegetation cover, health, and changes over time.

How NDVI is Calculated:

NDVI is calculated using the following formula:

$$\text{NDVI} = \frac{NIR-RED}{NIR+RED}$$

NIR (Near-Infrared Reflectance): Healthy vegetation strongly reflects NIR light.
RED (Red Light Reflectance): Healthy vegetation absorbs red light for photosynthesis.

NDVI Values and Their Meaning:
- NDVI ranges from -1 to +1:
- Negative values (near -1): Typically indicate water bodies, snow, or clouds.
- Values near 0 (0.1 to 0.2): Usually represent barren land, rock, or impervious surfaces like urban areas.
- Low positive values (0.2 to 0.4): Indicate sparse vegetation, such as shrubs or grasslands.
- High positive values (0.5 to 1): Represent dense, healthy green vegetation, like forests or well-irrigated crops.

Significance of NDVI:

1. Vegetation Health Monitoring:
 - NDVI is a direct indicator of photosynthetic activity, helping to assess the health and vigor of vegetation. Higher NDVI values suggest healthy, dense vegetation, while lower values indicate stressed or sparse vegetation.

2. Agricultural Applications:
 - Farmers and agronomists use NDVI to monitor crop conditions, optimize irrigation, assess drought impacts, and make informed decisions about fertilization and harvest times.

3. Environmental and Ecological Studies:
 - NDVI is crucial in studying land cover changes, deforestation, desertification, and the impact of natural disasters like fires and floods on vegetation.

4. Climate Change Research:
 - NDVI is used to observe long-term trends in vegetation health, which can be indicators of climate change impacts on ecosystems.

3)

- Enhanced Vegetation Index (EVI):

- Formula: EVI = G * (NIR - RED) / (NIR + C1 * RED - C2 * BLUE + L)
where G is a gain factor,
C_1 and C_2 are coefficients
L is a canopy background adjustment.
- Significance: EVI improves upon NDVI by reducing the influence of atmospheric conditions and soil background, making it more sensitive to differences in vegetation canopy structure. It is particularly useful in areas with dense vegetation.

- Soil-Adjusted Vegetation Index (SAVI):

- Formula: SAVI = (NIR - RED) / (NIR + RED + L) * (1 + L),
where L is a soil brightness correction factor.

-Significance: SAVI is designed to minimize soil brightness influences in areas with sparse vegetation. It is especially useful in arid regions where vegetation cover is low and soil exposure is significant.

- Green Normalized Difference Vegetation Index (GNDVI):

- Formula: GNDVI = (NIR - GREEN) / (NIR + GREEN)

-Significance: GNDVI uses the green band instead of the red band. It is more sensitive to chlorophyll content in vegetation and can be useful for monitoring crop health.

- Wide Dynamic Range Vegetation Index (WDRVI):

- Formula: WDRVI = (α * NIR - RED) / (α * NIR + RED),
where α is a weighting coefficient.

- Significance: WDRVI is an alternative to NDVI that increases sensitivity to vegetation changes, particularly in areas with dense vegetation, by adjusting the influence of NIR reflectance.

- Normalized Burn Ratio (NBR):

- Formula: NBR = (NIR - SWIR) / (NIR + SWIR)

-Significance: NBR is used to assess burned areas and the severity of fires. It compares near-infrared (NIR) and shortwave infrared (SWIR) reflectance, as vegetation is usually highly reflective in NIR and less so in SWIR.

- Vegetation Condition Index (VCI):

-Formula: VCI = (NDVI - NDVI_min) / (NDVI_max - NDVI_min)

- Significance: VCI is used to assess drought impacts on vegetation by comparing current NDVI values to the historical minimum and maximum. It is useful for monitoring the relative greenness of vegetation over time.

- Leaf Area Index (LAI):

- Significance: LAI measures the leaf area per unit ground area and is crucial for understanding canopy structure, light interception, and photosynthesis. It is often derived from NDVI or other remote sensing data.

3 Discussion

The obtained results demonstrate the distinct characteristics of MODIS and Landsat 8 data in capturing vegetation dynamics over the Lucknow region from 2014 to 2024. MODIS, with its coarser spatial resolution but higher temporal frequency, provides a smoother and more generalized NDVI time series. The consistent seasonal cycles in the MODIS data reflect its capability to monitor vegetation health on a macro scale. In contrast, Landsat 8, with its finer spatial resolution, reveals more pronounced and frequent fluctuations in NDVI values, indicating its sensitivity to localized changes in vegetation. These sharper peaks and troughs in the Landsat 8 data can be attributed to its ability to capture detailed changes in vegetation cover, which could be due to agricultural practices, urbanization, or natural events like floods and droughts that impact smaller areas more significantly. The differences in these results highlight the importance of choosing the appropriate satellite data based on the scale and focus of the study, with MODIS being more suited for broader regional analyses and Landsat 8 for detailed, localized assessments.

4 Conclusion

The exercise aimed to analyze the change in vegetation cover over a region using the NDVI, a critical indicator of vegetation health. By calculating NDVI over time for Lucknow, the goal was to produce a graph that reflects vegetation variation. The analysis was conducted using both Landsat 8 and MODIS data to compare the outputs from these different sources. The results showed that Landsat 8, with its higher spatial resolution, captured more detailed and localized variations in NDVI, leading to more pronounced peaks and troughs in the graph. In contrast, MODIS data, with its coarser resolution but higher temporal frequency, provided a smoother and more generalized view of vegetation trends over time. This comparison highlights the importance of selecting appropriate satellite data depending on the scale and specificity required for vegetation monitoring.

5 References

https://www.youtube.com/watch?v=Wik07UyjnDs
https://www.geospatialecology.com/lab2
https://www.youtube.com/watch?v=KFuihGDHE-s
https://iri.columbia.edu/~pceccato/Google_Training_Health/NDVI.pdf

6 Link to Codes

Landsat8 data-

- Band mean vs time series and filtering data- https://code.earthengine.google.com/bb5c0b35bc2a292d552b5c6fb100292e

MODIS data-

- Long term series data and Short term series data- https://code.earthengine.google.com/05f59595930adce9506d325d4d1b83ae

Comparison of both NDVI data time series-

- https://code.earthengine.google.com/582db22abeb2f57c86c181551a1619bc