



## **P2 : AI-BASED VEGETATION HEALTH & DENSITY MAPPING USING NDVI AND MACHINE LEARNING**

# **PROJECT REPORT**

**Prepared by : Akshita Mishra**

**Enrollment No : 418940**

**Designation : Master's Student in Geospatial Science**

**Institution: Delhi Technological University**

**Date of Submission : 18 Feb 2026**

# Table of Contents



**1. Objective**

**2. Study Area**

**3. Data Used**

**4. Bands Used**

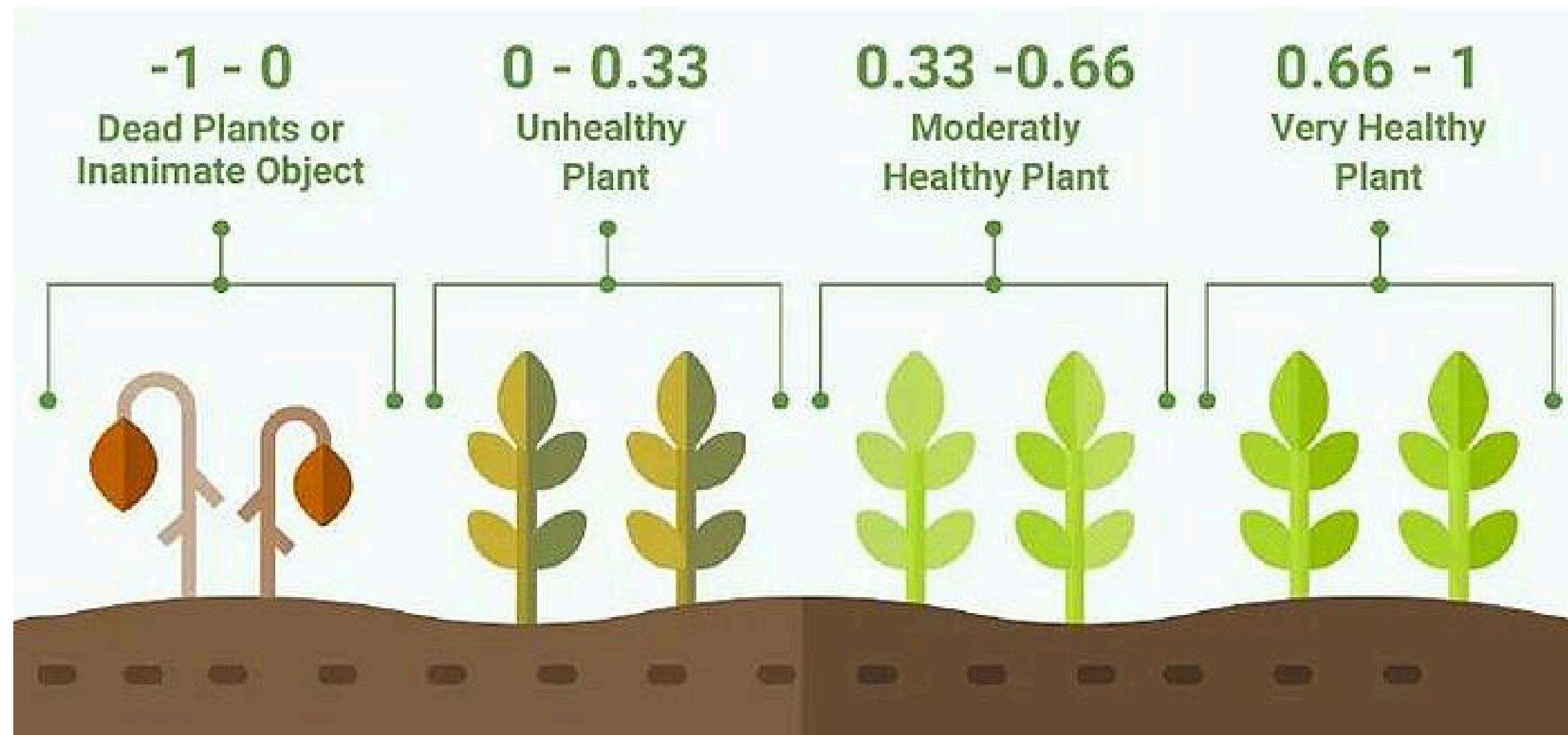
**5. Methodology**

**6. Results**

**7. Conclusion**

# Objectives

To assess vegetation health, density, and spatial distribution using the Normalized Difference Vegetation Index (NDVI) integrated with Artificial Intelligence (AI) and Machine Learning (ML) techniques, enabling improved classification accuracy, automated vegetation zoning, and enhanced interpretation compared to conventional threshold-based NDVI analysis



Source : <https://www.cropin.com/blogs/ndvi-normalized-difference-vegetation-index/>

# Study Area- Wayanad, Kerala, India

The study area selected for the present analysis is Wayanad District, located in the northeastern part of Kerala, India. The district lies in the Western Ghats region and is characterized by undulating terrain, dense forest cover, and high ecological sensitivity.

The district boundary shapefile was obtained by extracting the Wayanad district from the India administrative boundary ZIP file downloaded from DIVA-GIS, and QGIS was used to prepare the final map layout.”

The image displays two screenshots illustrating the process of extracting administrative boundaries for Wayanad District.

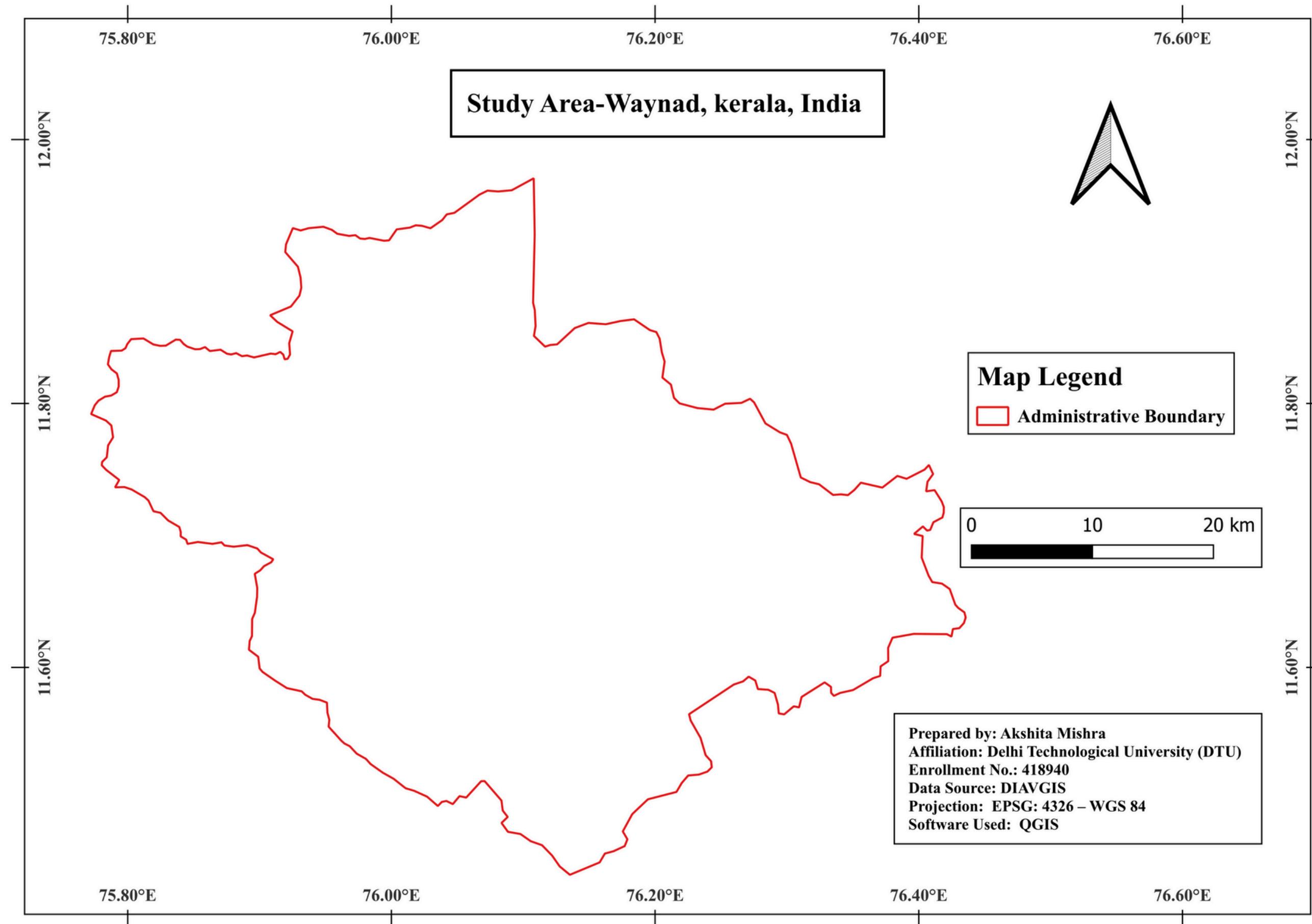
**Left Screenshot (DIVA-GIS):**

- Data:** The main section shows a dropdown menu for "Country" set to "India" and "Subject" set to "Administrative areas".
- Format:** A link to download "IND\_adm.zip".
- Sources:** A table listing the source information for the administrative boundaries.

Subject	Description	Source	Format	Resolution
Administrative areas (boundaries)	Country outlines and administrative subdivisions for all countries. The level of subdivisions that is available varies between countries	GADM	Vector (area)	-

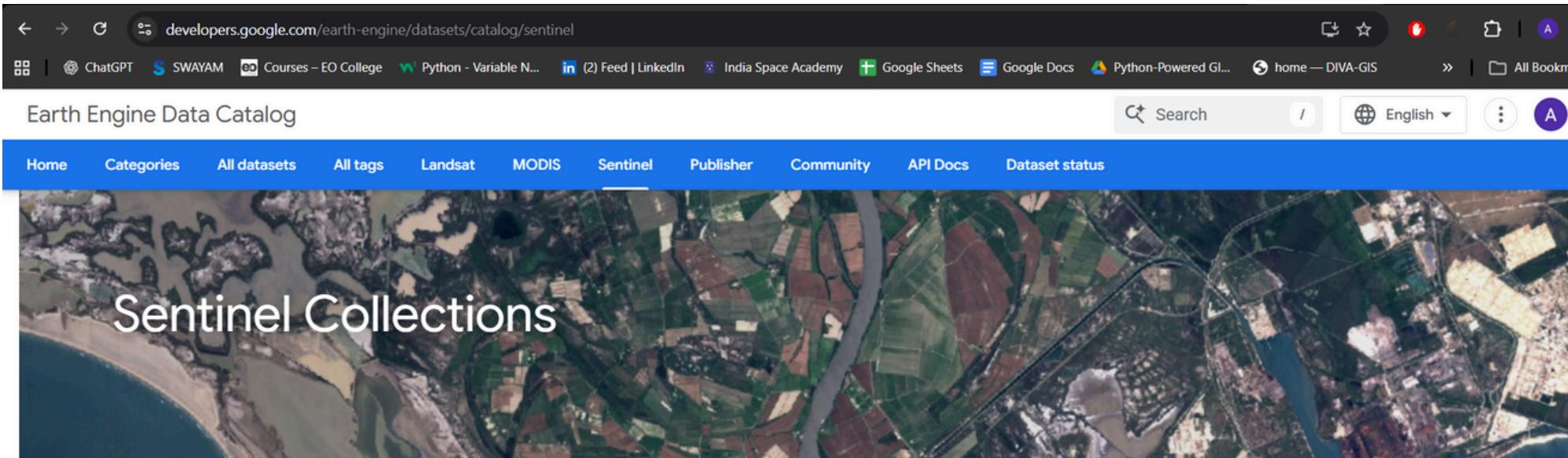
**Right Screenshot (QGIS):**

- Project:** WAYNAD — QGIS
- Layers:** The "Layers" panel shows several administrative boundary layers for India, with "gadm36\_IND\_3" selected. A sub-layer named "wayanad" is also listed.
- Map View:** The main canvas displays a map of India where the Wayanad district boundary is highlighted in red.
- Bottom Bar:** Includes coordinate information (33.74°, 103.99°), scale (1:17672118), magnification (100%), rotation (0.0°), and projection (EPSG:4326).



The final map layout was prepared in QGIS by incorporating standard cartographic elements such as title, legend, scale bar, north arrow, and coordinate grid.

# Data Set & Bands Used



The [Copernicus Program](#) is an ambitious initiative headed by the [European Commission](#) in partnership with the [European Space Agency \(ESA\)](#). The [Sentinels](#) are a constellation of satellites developed by ESA to operationalize the Copernicus program, which include all-weather radar images from Sentinel-1A and 1B, high-resolution optical images from Sentinel-2A and 2B, ocean and land data suitable for environmental and climate monitoring from Sentinel-3, as well as air quality data from Sentinel-5P.

If recent Sentinel data are missing in Earth Engine, please consult [the newsfeed on scihub](#) for known outages.

**Sentinel-2 multispectral data were accessed from Google Earth Engine (GEE), and Bands 4 and 8 were used for NDVI calculation.**

Dataset	Satellite	Bands Used	Spatial Resolution	Purpose
Sentinel-2 MSI	Sentinel-2	Band 4 (Red) Band 8 (NIR)	10–20 m	NDVI computation

A comparison of two Sentinel datasets. On the left, a Sentinel-1 SAR GRD (C-band Synthetic Aperture Radar) image shows a mountainous terrain with purple and green colors. On the right, a Sentinel-2 MSI (Multispectral Instrument) image shows a coastal area with fields, roads, and water bodies. Below each image is a brief description and availability information.

**Sentinel-1 SAR GRD: C-band Synthetic Aperture Radar**  
**Data availability:** 2014 – Present

The Sentinel-1 mission provides data from a dual-polarization C-band Synthetic Aperture Radar (SAR) instrument. SAR instruments are capable of acquiring meaningful data in all weather conditions (even clouds) during daytime and nighttime. Sentinel-1 data is used across many domains, including maritime activity, sea-ice mapping, humanitarian aid, crisis response, and forest management.

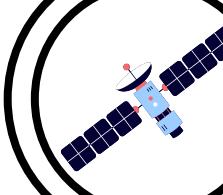
**Sentinel-2 MSI: Multispectral Instrument**  
**Data availability:** 2015 – Present

The Sentinel-2 mission collects high-resolution multispectral imagery useful for a broad range of applications, including monitoring of vegetation, soil and water cover, land cover change, as well as humanitarian and disaster risk.

# Methodology



**Study Area & Data Sources**



**Satellite Data Pre-processing**



**Vegetation Indices Generation (NDVI)**



**AI-Assisted Vegetation Classification**



**Accuracy Assessment & Area Statistics**

**STEP 1: Define Study Area (Wayanad Boundary)**- The study area boundary of Wayanad district, Kerala was extracted directly within Google Earth Engine using an administrative boundary FeatureCollection. The boundary was filtered using the district name attribute to isolate Wayanad. This approach ensures spatial accuracy and eliminates dependency on external shapefile uploads. The extracted boundary was visualized using a red outline to clearly demarcate the Area of Interest (AOI) without masking internal land cover details.

Google Earth Engine

Search places and datasets...

my-project-99883-sikkim

Scripts Docs Assets

New Script \* Get Link Save Run Reset Apps

Filter scripts... NEW

Owner (1)  
users/mishrakshita2203/ISA\_Projects  
ISA Project

Writer  
No accessible repositories. Click Refresh to check again.

Reader  
No accessible repositories. Click Refresh to check again.

Archive  
No accessible repositories. Click Refresh to

```
// Load district boundaries
var districts = ee.FeatureCollection("FAO/GAUL/2015/level2");

// Filter Wayanad district
var wayanad = districts
  .filter(ee.Filter.eq('ADM2_NAME', 'Wayanad'));

Map.centerObject(wayanad, 9);

// Display boundary (ONLY outline, not filled)
Map.addLayer(wayanad.style({
  color: 'red',
  fillColor: '00000000',
  width: 2
}), {}, 'Wayanad Boundary');
```

Inspector Console Tasks

Use print(...) to write to this console.

Layers

Map Satellite

Keyboard shortcuts Map data ©2026 20 km Terms Report a map error

**STEP 2: Selection of Season & Cloud-Free Sentinel-2 Imagery-** Sentinel-2 Surface Reflectance imagery was used due to its high spatial resolution (10 m) and suitability for vegetation analysis. The dataset was spatially filtered to the Wayanad district boundary and temporally filtered for the summer season (February–March 2023) to avoid monsoon-related cloud contamination. Images with cloud cover greater than 5% were excluded. A median composite was generated to further suppress residual cloud effects and clipped to the AOI for precise analysis.

Google Earth Engine
Search places and datasets...
?
my-project-99883-sikkim

Scripts
Docs
Assets

Filter scripts...
NEW

Owner (1)

- users/mishrakshita2203/ISA\_Projects
- ISA Project

Writer

No accessible repositories. Click Refresh to check again.

Reader

No accessible repositories. Click Refresh to check again.

Archive

No accessible repositories. Click Refresh to

New Script \*
Get Link 
Save 
Run 
Reset 
Apps

```

10 // Display boundary (ONLY outline, not filled)
11 Map.addLayer(wayanad.style({
12   color: 'red',
13   fillColor: '00000000',
14   width: 2
15 }), {}, 'Wayanad Boundary');
16
17 // Load Sentinel-2 Surface Reflectance data
18 var s2 = ee.ImageCollection('COPERNICUS/S2_SR_HARMONIZED')
19 .filterBounds(wayanad)
20 .filterDate('2023-02-01', '2023-03-31')
21 .filter(ee.Filter.lt('CLOUDY_PIXEL_PERCENTAGE', 5))
22 .median()
23 .clip(wayanad);
24
25

```

Inspector
Console
Tasks

Use print(...) to write to this console.

**Why Summer Season Was Selected?**

The summer season was selected due to active agricultural conditions and minimal cloud cover compared to the monsoon period. These factors ensure clearer satellite imagery and more reliable NDVI values for accurate vegetation analysis.

**Selected period: February–March 2023**

Map
Satellite

Keyboard shortcuts | Map data ©2026 | 20 km | Terms | Report a map error

**STEP 3: Pre-Processing – True Color Composite (TCC)**- A TCC was generated using Sentinel-2 bands Red (B4), Green (B3), and Blue (B2) to simulate natural color visualization. This step aids in visual verification of land cover, identification of vegetation, water bodies, and built-up areas, and serves as a reference for validating subsequent vegetation indices and classifications.

Google Earth Engine

Search places and datasets...

my-project-99883-sikkim

Scripts Docs Assets

Filter scripts... NEW

Owner (1)  
users/mishrakshita2203/ISA\_Projects  
ISA Project  
Waynad

Writer  
No accessible repositories. Click Refresh to check again.

Reader  
No accessible repositories. Click Refresh to check again.

Archive

Waynad

Get Link Save Run Reset Apps

Inspector Console Tasks

Use print(...) to write to this console.

```
19 .filterBounds(wayanad)
20 .filterDate('2023-02-01', '2023-03-31')
21 .filter(ee.Filter.lt('CLOUDY_PIXEL_PERCENTAGE', 5))
22 .median()
23 .clip(wayanad);
24
25 // True Color Composite (RGB)
26 var tcc = {
27   bands: ['B4', 'B3', 'B2'],
28   min: 0,
29   max: 3000
30 };
31
32 Map.addLayer(s2, tcc, 'True Color Composite');
33
34
```

Kannur

Gundlupete

Mudumalai

Gudalur

Chamarajanagar

Anthiyur

Gobichettinallayam

Vatakara

Perambra

Kuttiady

Thalassery

Kuthuparamba

Kannur

Gudalur

Chamarajanagar

Anthiyur

Gobichettinallayam

Keyboard shortcuts

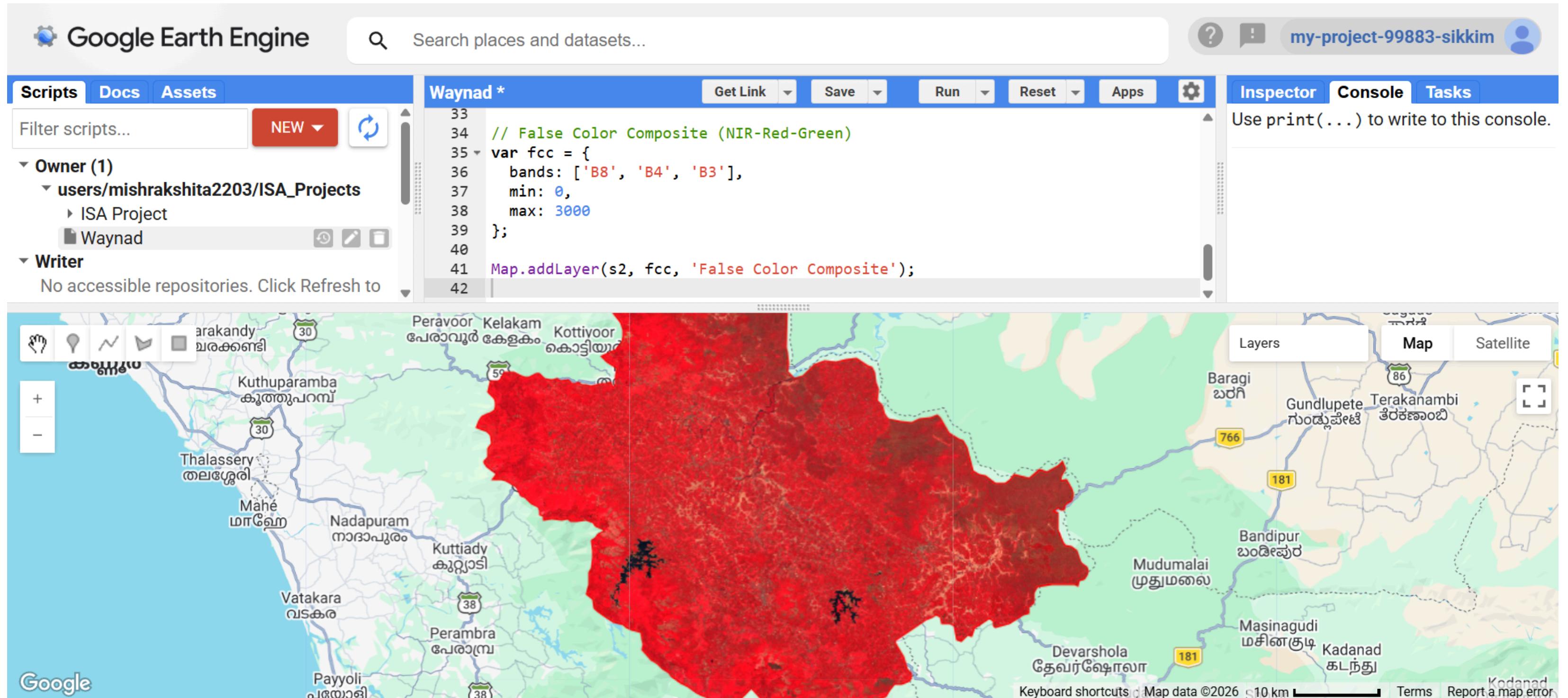
Map data ©2026

20 km

Layers

Map Satellite

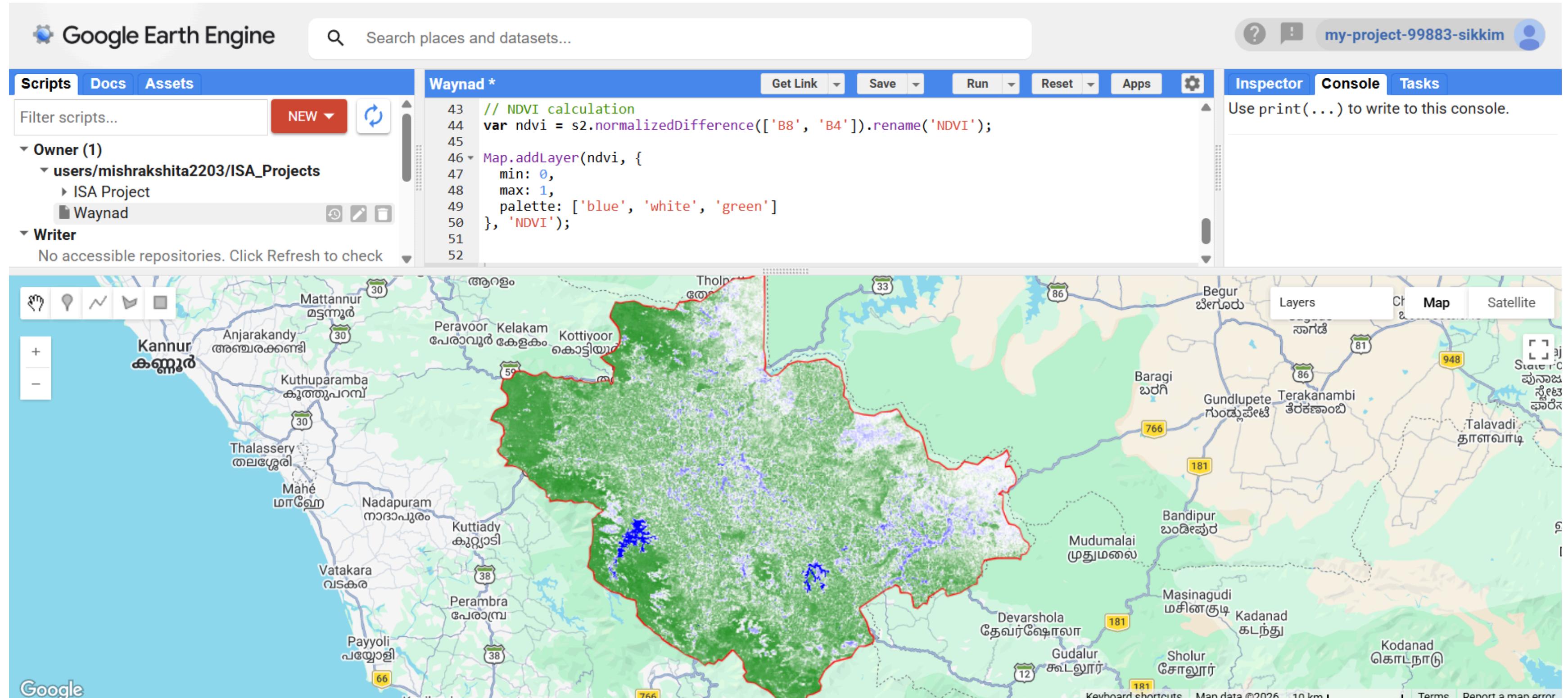
**STEP 4: False Color Composite (FCC)**- A False Color Composite (FCC) was created using Near Infrared (B8), Red (B4), and Green (B3) bands. Vegetation appears in shades of red due to high reflectance in the NIR region, making FCC highly effective for distinguishing vegetation density and health. This visual enhancement supports interpretation prior to NDVI computation.



**STEP 5: NDVI Calculation-** The Normalized Difference Vegetation Index (NDVI) was computed using the standard formula

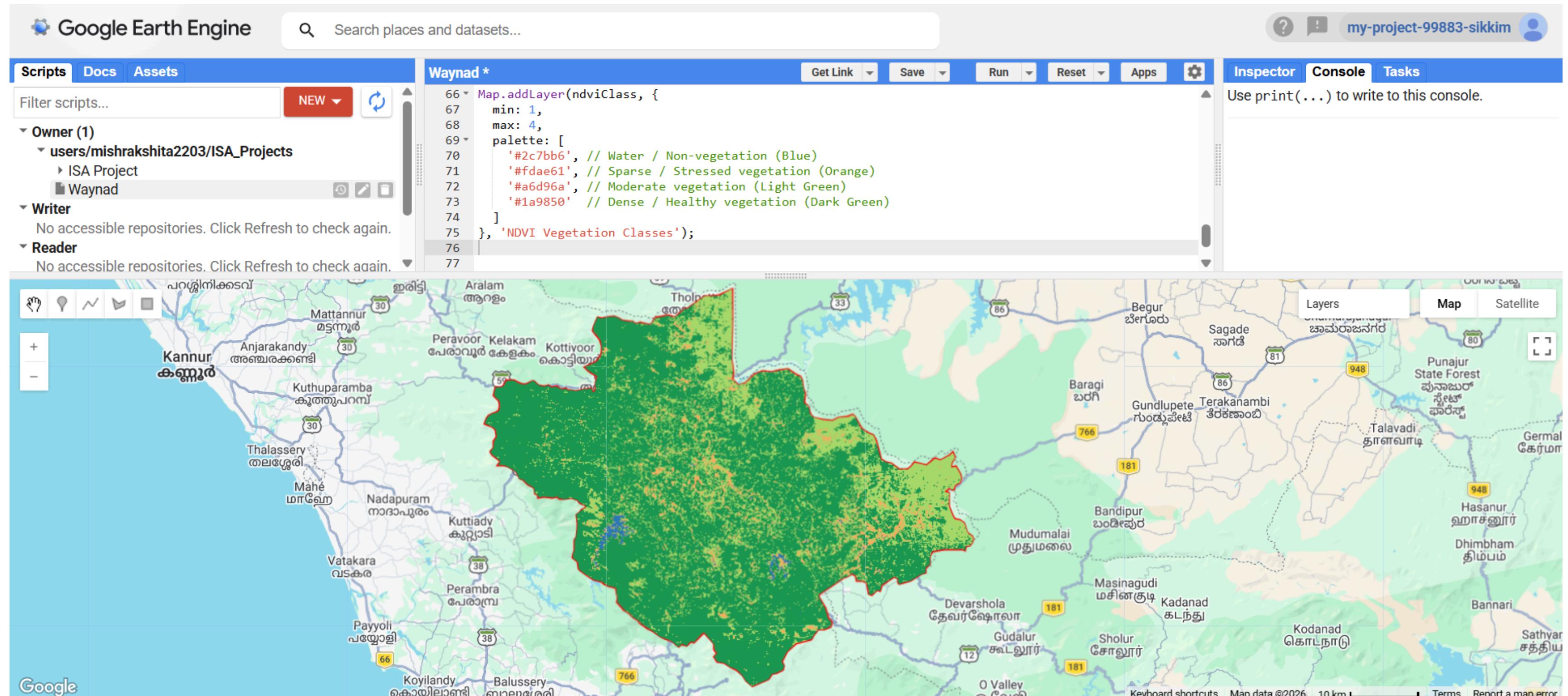
$$\text{NDVI} = (\text{NIR} - \text{Red}) / (\text{NIR} + \text{Red})$$

where Band 8 (NIR) and Band 4 (Red) of Sentinel-2 were used. NDVI values range from  $-1$  to  $+1$ , with higher values indicating healthier and denser vegetation. The resulting NDVI raster provides a continuous representation of vegetation vigor across the study area.



**STEP 6: AI-Inspired NDVI Classification (Adaptive Vegetation Zoning)**- The NDVI raster was clipped to the Wayanad district boundary prior to classification to avoid background misclassification. An AI-inspired rule-based logic was applied to adaptively group NDVI values into four vegetation health categories. Masking was applied to remove null pixels outside the study area, ensuring spatial precision.

**STEP 7: Improved Color Coding for Vegetation Classes-** A scientifically standardized color palette was applied to represent vegetation health classes. Blue represents water and non-vegetated areas, orange indicates sparse or stressed vegetation, while light and dark green represent moderate to dense vegetation respectively. This color scheme improves visual clarity and interpretability of vegetation patterns.



**STEP 8: Post-Classification Noise Reduction**- A focal mode filter was applied to the classified NDVI raster to reduce salt-and-pepper noise caused by mixed pixels. This spatial refinement simulates AI-based post-processing and improves class continuity, resulting in a smoother and more realistic vegetation map.

Google Earth Engine

Search places and datasets...

my-project-99883-sikkim

Scripts Docs Assets

Filter scripts... NEW

Owner (1)  
users/mishrakshita2203/ISA\_Projects  
ISA Project  
Waynad

Writer  
No accessible repositories. Click Refresh to check again.

Reader  
No accessible repositories. Click Refresh to check again.

Archive  
No accessible repositories. Click Refresh to check again.

Examples

Waynad \*

```
77 var ndviFiltered = ndviClass.focal_mode({  
78   radius: 1,  
79   units: 'pixels'  
80 });  
81  
82 Map.addLayer(ndviFiltered, {  
83   min: 1,  
84   max: 4,  
85   palette: [  
86     '#2c7bb6',  
87     '#fdae61',  
88     '#a6d96a',  
89     '#1a9850'  
90   ]  
91 }, 'Filtered NDVI Classes');
```

Inspector Console Tasks

Use print(...) to write to this console.

**STEP 9: Area Statistics for Vegetation Health Classes-** Area statistics were computed for each vegetation health class by combining pixel-level area information with the classified NDVI raster. This quantitative analysis supports objective assessment of vegetation distribution across the study area.

Google Earth Engine

Search places and datasets...

my-project-99883-sikkim

Scripts Docs Assets

Filter scripts... NEW

Owner (1)  
users/mishrakshita2203/ISA\_Projects  
ISA Project Waynad  
Writer  
No accessible repositories. Click Refresh to check again.  
Reader  
No accessible repositories. Click Refresh to check again.  
Archive  
No accessible repositories. Click Refresh to check again.  
Examples

Waynad \*

```
92 // Prepare image with class + pixel area
93 var areaImage = ee.Image.pixelArea()
94 .addBands(ndviFiltered);
95
96 // Calculate area statistics class-wise
97 var areaStats = areaImage.reduceRegion({
98   reducer: ee.Reducer.sum().group({
99     groupField: 1,      // NDVI_Class band index
100    groupName: 'NDVI_Class'
101   }),
102   geometry: wayanad,
103   scale: 10,
104   maxPixels: 1e13
105 });
106
107 // Print results
108 print('Vegetation Class Area (sq. meters):', areaStats);
109
110
```

Inspector Console Tasks

Vegetation Class Area (sq. meters): JSON

Object (1 property)

- groups: List (4 elements)
  - 0: Object (2 properties)
    - NDVI\_Class: 1
    - sum: 27867137.432085287
  - 1: Object (2 properties)
    - NDVI\_Class: 2
    - sum: 139536887.38863224
  - 2: Object (2 properties)
    - NDVI\_Class: 3
    - sum: 470613701.4386151
  - 3: Object (2 properties)
    - NDVI\_Class: 4
    - sum: 1483927226.0905848

Map Satellite

Payyanur പയ്യനൂർ Parassinikadavu പരസ്സിനിക്കടവ് Iritty ഇരിട്ട് Kannur കന്നുര് Kuthuparamba കുത്തപ്പൻവ് Thalassery തലശ്ശേരി Vatakara വടക്കര Kuttiady കുറ്റാടി Perambra പേരാമ്പ് Koyilandy കോയിലാംബ് Thamarassery താമരക്കുറി Mudumalai മുതുമലை Gudalur കുടലൂർ Ooty ഉതകമண്ടലം Nilambur Mettupalaya Gobichettipalayam കോപിച്ചെട്ടിപ്പാളായം Erode Rasipuram Edappadi എടപ്പാടി Salem ചേലം Hanur ഹനൂർ Male മെൽസ്സേര് സില്ല് Mettur മേട്ടുര് Omalur ഓമലൂർ Yer എറ്റ്

**STEP 10:** The calculated areas were further converted **from square meters to square kilometers** to facilitate easy interpretation and reporting in standard geographic units.

Google Earth Engine

Search places and datasets...

Scripts Docs Assets NEW Filter scripts... Waynad \*

Owner (1) users/mishrakshita2203/ISA\_Projects ISA Project Waynad Writer Reader Archive Examples

No accessible repositories. Click Refresh to check again.

Get Link Save Run Reset Apps Inspector Console Tasks

```
// Calculate area statistics class-wise
var areaStats = areaImage.reduceRegion({
  reducer: ee.Reducer.sum().group({
    groupField: 1, // NDVI_Class band index
    groupName: 'NDVI_Class'
  }),
  geometry: wayanad,
  scale: 10,
  maxPixels: 1e13
});

// Print results
print('Vegetation Class Area (sq. meters):', areaStats);

// Convert sq. meters to sq. km
var classAreas = ee.List(areaStats.get('groups')).map(function(item) {
  item = ee.Dictionary(item);
  return item.set('Area_sq_km',
    ee.Number(item.get('sum')).divide(1e6)
  );
});

print('Vegetation Class Area (sq. km):', classAreas);
```

Vegetation Class Area (sq. km): JSON

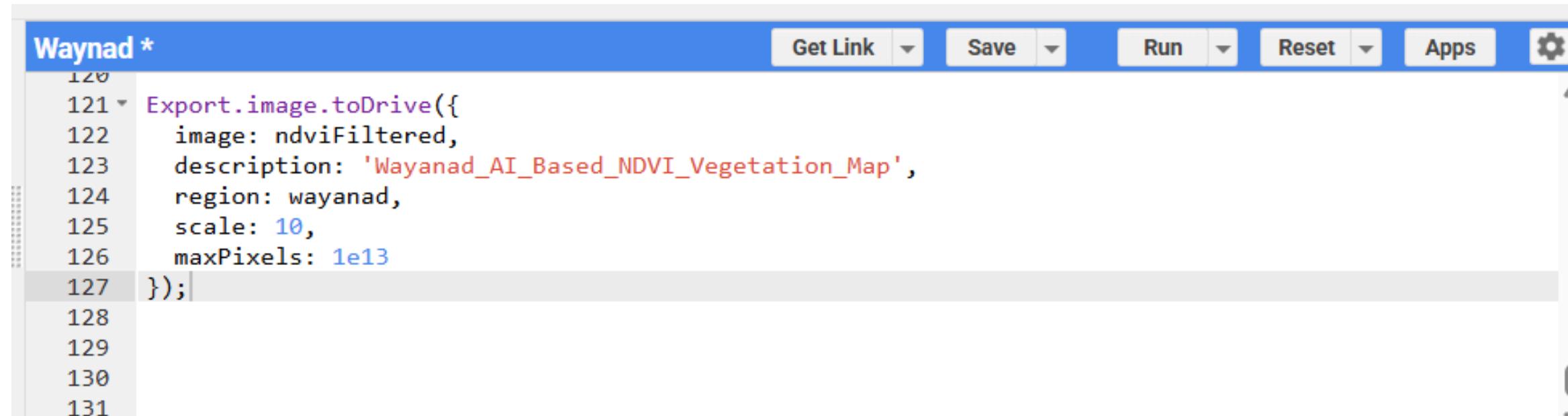
List (4 elements) JSON

- 0: Object (3 properties)  
Area\_sq\_km: 27.867137432085286  
NDVI\_Class: 1  
sum: 27867137.432085287
- 1: Object (3 properties)  
Area\_sq\_km: 139.53688738863224  
NDVI\_Class: 2  
sum: 139536887.38863224
- 2: Object (3 properties)  
Area\_sq\_km: 470.61370143861507  
NDVI\_Class: 3  
sum: 470613701.4386151
- 3: Object (3 properties)  
Area\_sq\_km: 1483.9272260905848  
NDVI\_Class: 4  
sum: 1483927226.0905848

Layers Map Satellite

Keyboard shortcuts Map data ©2026 20 km Terms Report a map error

**STEP 11: The final AI-assisted NDVI vegetation health and density map was exported from Google Earth Engine to Google Drive at a spatial resolution of 10 meters.**



The screenshot shows the Google Earth Engine code editor with a blue header bar containing buttons for 'Get Link', 'Save', 'Run', 'Reset', 'Apps', and a gear icon. Below the header is a tab labeled 'Waynad \*'. The main area contains the following code:

```
120
121 Export.image.toDrive({
122   image: ndviFiltered,
123   description: 'Wayanad_AI_Based_NDVI_Vegetation_Map',
124   region: wayanad,
125   scale: 10,
126   maxPixels: 1e13
127 });
128
129
130
131
```

To the right of the code editor is a sidebar with tabs for 'Inspector', 'Console', and 'Tasks'. The 'Tasks' tab is selected, displaying a message about searching or canceling tasks in the Task Manager or Tasks Page in the Cloud Console. Below this is a section titled 'SUBMITTED TASKS' which lists a single task named 'Wayanad\_AI\_Based\_NDVI\_Vegetation\_Map' with a status of '<1m'.

Exporting the processed output enables its integration with desktop GIS software such as QGIS for further spatial analysis, cartographic layout preparation, and inclusion in the final project report. This step ensures data reproducibility, long-term storage, and usability of results beyond the cloud-based processing environment.

**Task: Initiate image export**

Task name (no spaces)\*  
Wayanad\_AI\_Based\_NDVI\_Vegetation\_Map

Coordinate Reference System (CRS)  
EPSG:3857

Scale (m/px)  
10

**DRIVE**   **CLOUD STORAGE**   **EE ASSET**

Drive folder  
Drive folder name or blank for root

Filename\*  
Wayanad\_AI\_Based\_NDVI\_Vegetation\_Map

File format\*  
GEO\_TIFF

**CANCEL**   **RUN**

# Result

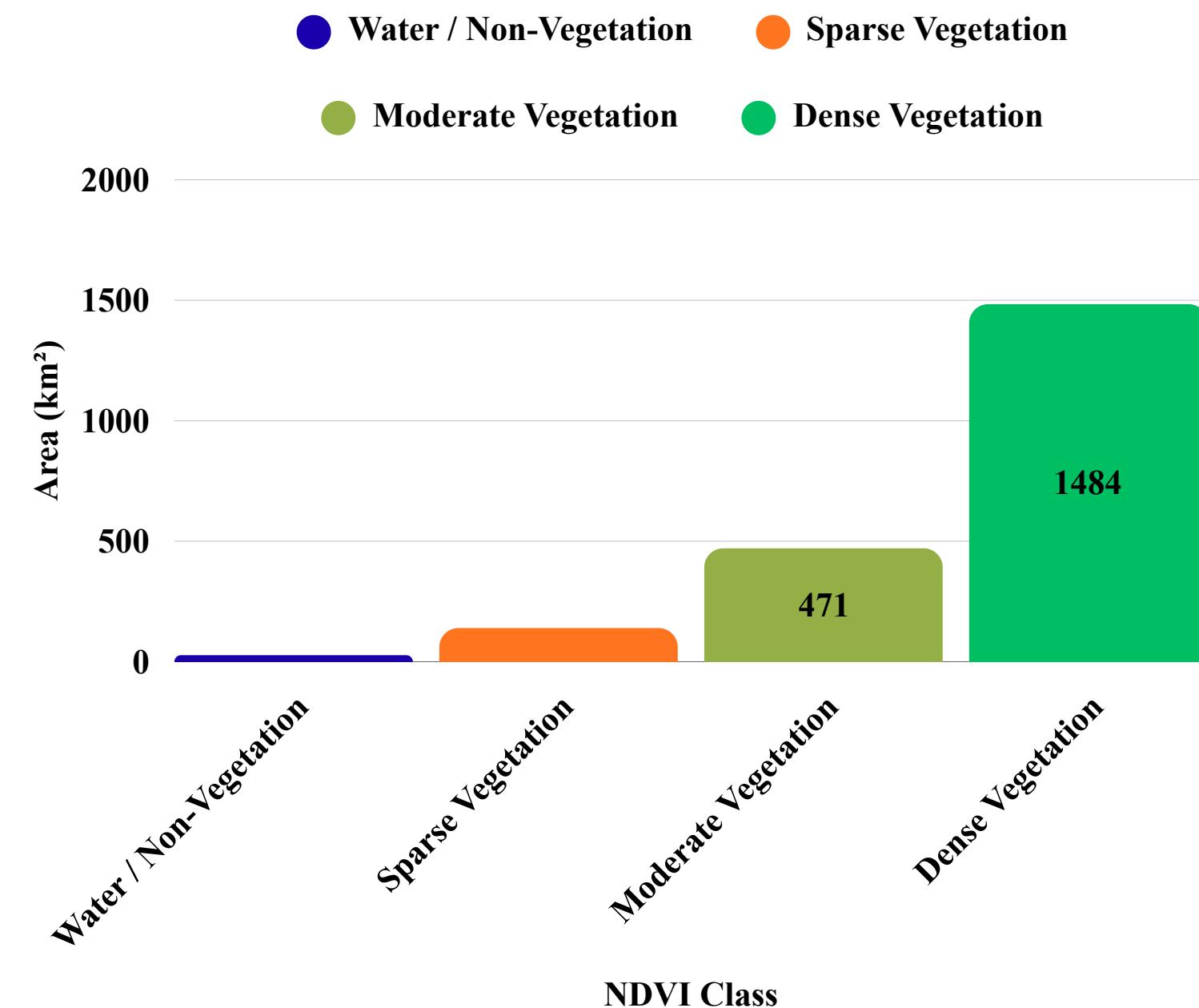


- Continuous NDVI raster representing vegetation vigor
- AI-assisted classified vegetation health and density map
- Area statistics for each vegetation class
- Final cartographic layouts suitable for reporting and analysis

The AI-based NDVI analysis revealed that Wayanad district is predominantly covered by dense and healthy vegetation, particularly in forested and plantation regions such as Brahmagiri Wildlife Sanctuary, Wayanad Wildlife Sanctuary, and the forest belts around Thirunelli and Muthanga. These areas exhibit consistently high NDVI values, indicating dense canopy cover and healthy vegetation conditions.

Moderate vegetation was observed mainly in agricultural and mixed land-use zones, especially around Kalpetta, Mananthavady, and Sulthan Bathery, where plantation crops, croplands, and scattered settlements coexist. Sparse vegetation and non-vegetated regions were limited in extent and were primarily associated with urban settlements, road networks, water bodies, and exposed surfaces, particularly in localized pockets around town centers and river courses.

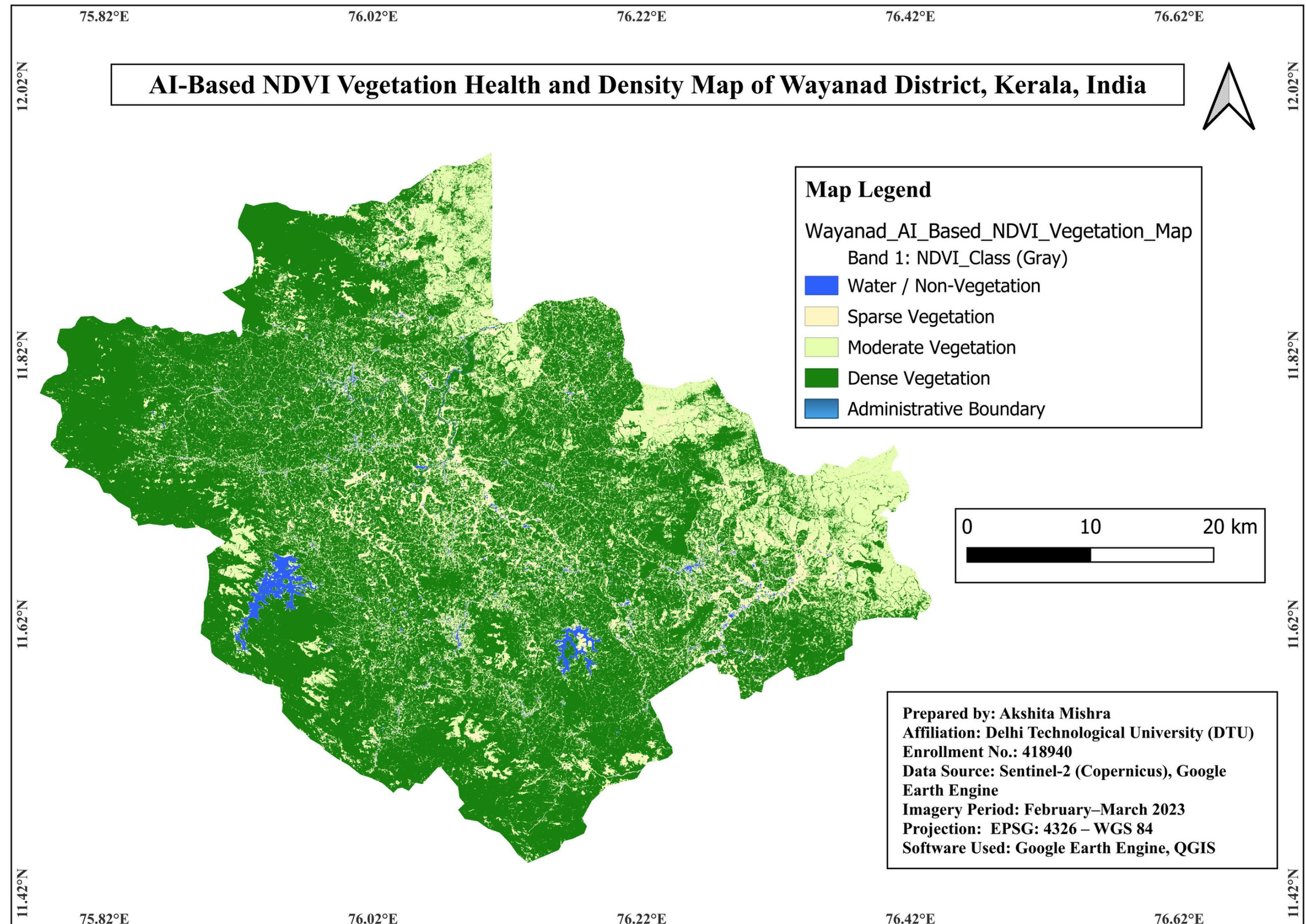
**Area Statistics of NDVI-Based Vegetation Classes**



# Conclusion

This study demonstrates the effectiveness of integrating Artificial Intelligence-inspired classification techniques with NDVI-based vegetation analysis using Google Earth Engine. The adaptive rule-based approach improved classification consistency and reduced noise compared to traditional fixed-threshold NDVI methods.

The results highlight the dominance of healthy vegetation in Wayanad district and confirm the suitability of cloud-based geospatial platforms for large-area environmental monitoring. Despite limitations related to seasonal variability and atmospheric effects, the methodology provides a reliable framework for vegetation assessment in agricultural, forest, and environmental applications.



# **Limitations & Future Scope**

## **Limitations**

- NDVI is sensitive to soil background and seasonal changes.
- Cloud shadows may still influence results despite filtering.
- Rule-based classification approximates AI but does not replace full ML models.

## **Future Scope**

- Integration of machine learning classifiers (Random Forest, SVM).
- Use of multi-temporal NDVI for seasonal trend analysis.
- Incorporation of additional indices such as EVI and SAVI.

# References

1. Cropin. (n.d.). Normalized Difference Vegetation Index (NDVI). Retrieved from <https://www.cropin.com/blogs/ndvi-normalized-difference-vegetation-index/>
2. Google Earth Engine. (2023). NDVI calculation tutorial. [https://developers.google.com/earth-engine/tutorials/tutorial\\_api\\_06](https://developers.google.com/earth-engine/tutorials/tutorial_api_06)
3. IJCmas. (2021). Application of NDVI in vegetation monitoring using Sentinel-2 time series.
4. ResearchGate. (2026). Landscape transformation in Wayanad district using NDVI.
5. Sha, K. (2020). NDVI variability over Kerala using satellite observations.

