Satellite Farming: Download, Detect, and Decide with Multispectral Imagery

Ali Mirzakhani Nafchi, Assistant Professor & SDSU Extension Precision Agriculture Specialist
Karishma Kumari, Graduate Research Assistant
Jose Payero, Assistant Professor, Irrigation Specialist, Clemson University
Hankui Zhang, Associate Professor, Research Scientist
John McMaine, Associate Extension Professor, University of Kentucky

June 2025

Multispectral Indices in Precision Agriculture

Multispectral imagery (MSI) from satellites offers repeated, wide-area observations of farmland using specific wavelengths of light. From the reflectance of various bands, e.g., visible RGB (red/green/blue), near-infrared (NIR), and shortwave infrared (SWIR), we can derive vegetation indices related to crop health, water status, nutrient stress, and yield potential. Today, satellite-based MSI, unlike drone and conventional field scouting which are often time-consuming and limited in scope, allows producers and crop advisors to assess entire fields at once repeatedly throughout the season. For farmers and agronomists, this imagery can be translated into decision-making tools to support crop production.

NDVI (Normalized Difference Vegetation Index) and NDRE (Normalized Difference Red Edge) extracted from spectral bands allow growers to assess plant vigor over time. For example, a wheat or barley grower can monitor canopy development and crop damage caused by extreme weather/disease by observing changes in NDVI values. A steady increase in NDVI (before the senescence begins) could indicate healthy biomass accumulation, whereas plateaus or declines could point to underlying issues such as compaction or disease. For corn, imagery during early vegetative stages could help evaluate emergence and crop development during the leaf development phase. Deviations in NDVI across a field may reveal variability in growth rate due to soil heterogeneity or stand gaps. Also, MSI in the near-infrared and shortwave infrared (SWIR) can reflect the plant's water content and physiological stress responses in irrigated land. MSI can guide irrigation scheduling down to specific management zones when coupled with thermal sensors or ground truth data. On the other hand, satellite MSI in nutrient management can discover how nutrient deficiencies affect plant chlorophyll, which alters how leaves reflect and absorb light, changes easily captured by indices like EGI (Excess green index), GNDVI (Green NDVI), and NDRE. These indices allow agronomists and crop advisors to generate variable-rate application maps, increasing fertilizer efficiency while minimizing environmental impact.

In corn, nitrogen stress is often detected using NDRE derived from the red edge bands in the V6 to V12 growth stages when the plant's nutrient demands surge. Healthy corn shows very low red reflectance and high near-infrared (NIR, > 700 nm) reflectance, producing a steep slope across the red-edge region (~705–740 nm). Leaves absorb red light red light (~660 nm) because that wavelength matches the main chlorophyll-an absorption peaks, during photosynthesis (Fig. 1). While near-infrared (> 700 nm) photons carry too little energy to excite those pigment transitions, so they pass into the spongy mesophyll and are multiply scattered back out by the air-cell-wall interfaces with high reflection. Because chlorophyll loss or structural damage flattens that red absorption but leaves the NIR scattering almost untouched, the steep "red-edge" slope shifts toward shorter wavelengths long before NDVI starts to fall. Hence red-edge indices such as NDRE pick up nitrogen-stress signals in V6–V12 corn earlier and more sensitively than classic red-NIR pairs (e.g., NDVI). Study of other indices also can reveal NDRE can highlight areas with declining chlorophyll before symptoms are visible to the naked eye.

The EGI effectively suppresses the red and blue components of an image while boosting the green component, making it easier to distinguish vegetation from non-vegetative elements like background or soil. Therefore, this index is useful for identifying areas with green cover and distinguishing between crops and weeds based on their greenness. GNDVI can guide top and side-dressing applications, ensuring nitrogen is applied where needed. Also, analyzing multispectral imagery over time can offer estimates of expected yield. This is done by correlating seasonal NDVI trends with historical yield data to develop biomass models that estimate crop productivity weeks before harvest. Finally, multispectral satellite imagery excels at early crop stress detection or damage assessment, whether from pests, diseases, or abiotic factors like heat, drought, or salinity.

Bringing It All Together

Satellite-based multispectral imagery transforms how farmers and agricultural professionals interact with their fields. Stakeholders can access timely, high-resolution data to drive smarter decisions, adjust irrigation zones, fine-tune nutrient applications, or modeling yield potential. As access to satellite data becomes more affordable and platforms grow increasingly user-friendly, the barrier to adoption continues to fall. Platforms like Sentinel Hub, EOS Crop Monitoring, and Climate FieldView enable even small-scale producers to harness these insights from space.

Sentinel-2 Data

Landsat remains the flagship of the U.S. Earth-observation program: Landsat 8 (2013) and Landsat 9 (2021) each collect nine optical bands at 30 m resolution across a 185 km swath, revisiting every 16 days for an effective eight-day composite when both are operating. Widely applied in agricultural monitoring, the Landsat archive offers unmatched radiometric stability and historical depth, while Sentinel-2 adds finer spatial detail, additional red-edge bands, and a five-day revisit ideal for tracking crop phenology and rapid disaster impacts. Together, these free and interoperable datasets form a complementary optical backbone for Earth-observation science and applications.

The Sentinel-2's constellation delivers 10-band multispectral imagery at 10 m (visible–NIR), 20 m (red-edge–SWIR) designed for land applications (Table 1) across a 290 km swath, with each spacecraft (Sentinel-2A launched 23 June 2015 and Sentinel-2B on 7 March 2017) revisiting any point on Earth every ten days; flown 180° apart, they halve that cycle to about five days at the Equator, a cadence now safeguarded by Sentinel-2C, lofted on 5 September 2024 to take over as 2A nears end-of-life. Free and open-access Sentinel-2 data is publicly available, supporting a wide range of global research and practical applications in agriculture, environmental monitoring, and more.

Sentinel-2A 2B, and 2C key features

The vegetation spectral reflectance across different wavelengths and explains how satellites like Sentinel-2 detect and enable continuous monitoring of vegetation,

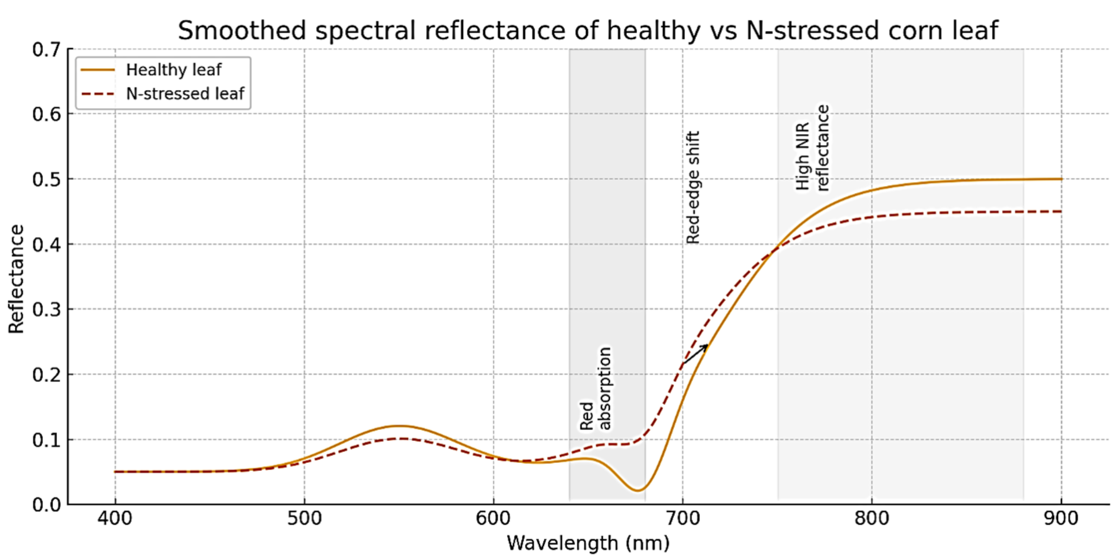

Figure 1. Illustration of reflectance red edge shift of the healthy and N-stressed leaves.

agriculture, forests, and water resources. Across the spectrum from ~400 to 2200 nm reflectance shows how much light is reflected by the surface at different wavelengths. In visible range wavelengths (~450 to 670 nm) with a low reflectance light is absorbed by chlorophyll in healthy vegetation and causes vegetation to appear green, as green light is reflected. In NIR range wavelengths (around 750-950 nm), healthy plants with a strong NIR reflectance due to cell structure, used in indices like NDVI and GNDVI to assess plant health. Water in plant leaves strongly absorbs SWIR wavelength ranges (around 1400-1900 nm), and reflectance drops significantly in water-absorbing bands, which can be used for detecting plant moisture content or drought stress.

Table 1. Sentinel-2A, 2B and 2C with 13 spectral bands for calculating different indices.

Band	Name	Wavelength (nm)	Resolution (m)	Primary Applications
B01	Coastal aerosol	443	60	Atmospheric correction, coastal studies
B02	Blue	490	10	Bathymetric mapping, soil/vegetation discrimination
B03	Green	560	10	Vegetation health, water body analysis
B04	Red	665	10	Vegetation monitoring, urban mapping
B05	Red Edge 1	705	20	Chlorophyll content, vegetation stress
B06	Red Edge 2	740	20	Leaf area index, plant health
B07	Red Edge 3	783	20	Biomass estimation, vegetation classification
B08	NIR	842	10	Vegetation vigor, biomass, water body delineation
B8A	Narrow NIR	865	20	Vegetation structure, canopy analysis
B09	Water vapor	945	60	Atmospheric correction
B10	SWIR – Cirrus	1375	60	Cirrus cloud detection
B11	SWIR 1	1610	20	Soil moisture, vegetation water content
B12	SWIR 2	2190	20	Snow/ice/cloud discrimination, geological mapping

The red, green, and blue lines in Figure 2 represent the spectral reflectance of different level of healthiness: healthy vegetation (green), moderately stressed vegetation (blue), and stressed vegetation (red).

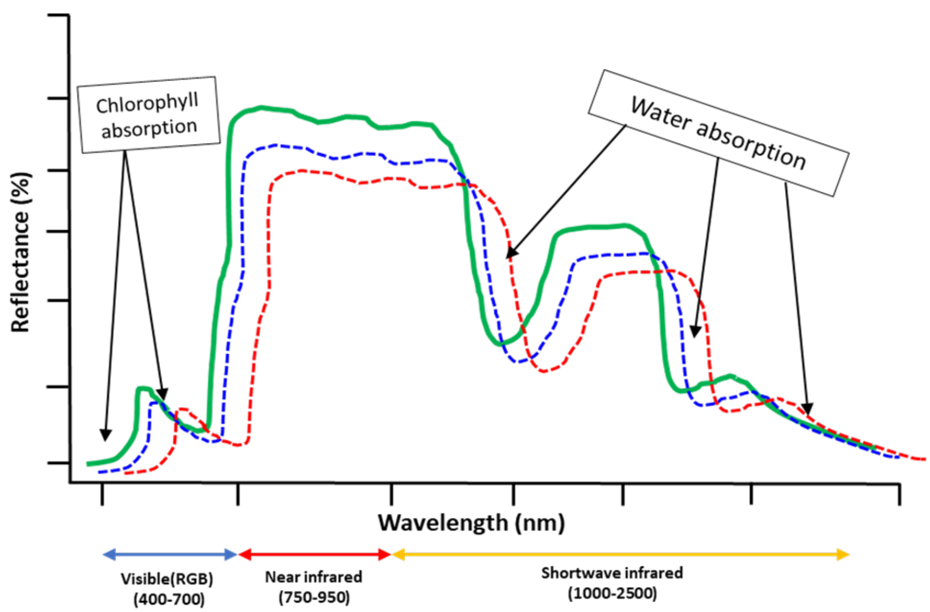

Figure 2. Vegetation reflectance spectrum: illustrating chlorophyll absorption in the visible range (RGB) and water absorption in the SWIR. Sentinel-2A/2B uses these bands for frequent vegetation and surface monitoring.

These bands are instrumental in various applications, including agriculture, forestry, water resource management, and environmental monitoring. For instance, combinations of these bands can be used to calculate indices like the Normalized Difference Vegetation Index (NDVI), Green Normalized Difference Vegetation Index (GNDVI), and the Normalized Difference Water Index (NDWI), which can assess vegetation health, chlorophyll concentration in plants, and water content, respectively.

Step-by-Step Guide to Download and Process Sentinel Satellite MSI Images to get EGI image

EGI (Excess Green Index and EGI = 2R - (G+B) is a vegetation index used in image analysis to detect green vegetation using RGB images, effective for crop detection, canopy cover estimation, and plant segmentation.

Visit the Copernicus Open Access Hub website

- To download the sentinel satellite images, go to the website by clicking on this link: https://browser.dataspace.copernicus.eu/
- This website provides access to European Space Agency (ESA) satellite images.

Sign-up and log-in

- Click on green color Register option to create an account if you are a new user (Fig. 3).
- Fill in your details (name, country, email, password, etc.) on the popped form and create a username and password.
- Check your email for a confirmation link and verify your account and return to the website and click on Log In. Enter your username and password to enter in the main environment (Fig. 4).

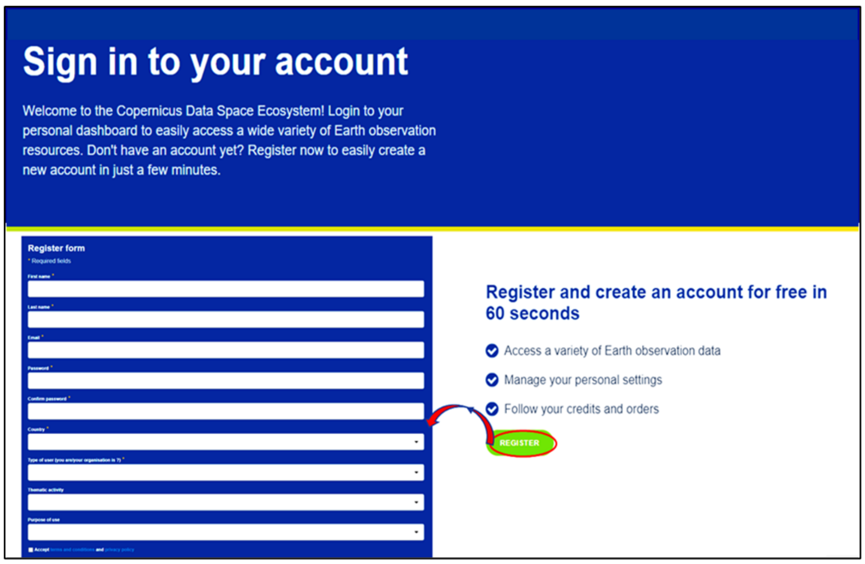

Figure 3. User registration page to create your account in the Copernicus data space ecosystem

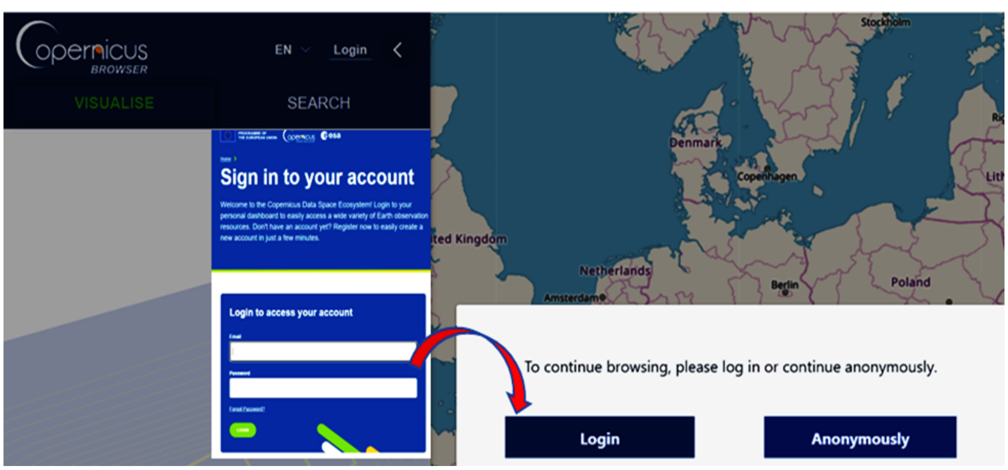

Figure 4. Copernicus browser login page using your account credentials

Choose your area of interest (AOI)

- Once logged in, use the mouse to pan and zoom to your area of interest AOI (Fig. 5).
- Draw the rectangle over the area of interest by clicking on polygon symbol.

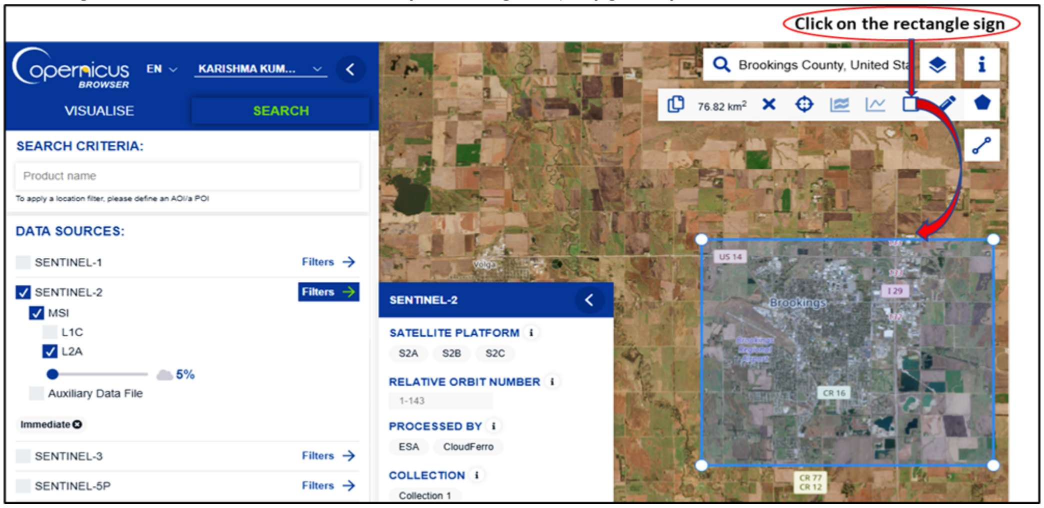

Figure 5. Page to search for satellite images for a specific location by defining an Area of Interest (AOI) using different polygon shape options

Search for images

- Click on the Search tab in the top menu (Fig. 6).
- Use the filters (Data sources) on the left side of the screen to refine your search:
  - **Time Range:** Select a date range (from and until) to find recent images.
  - **Mission:** Choose Sentinel-2 (MSI, L2A) for land images.
  - **Cloud Cover:** Set it to 5% for clear images.
- Click the Search button, and a list of available images will appear.

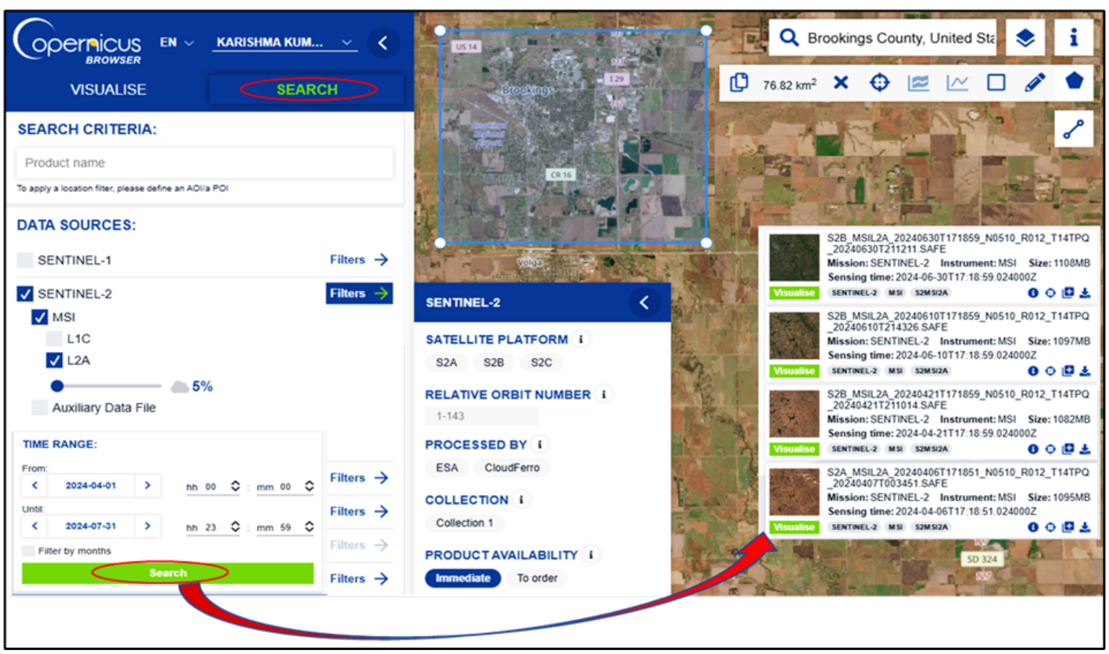

Figure 6. Page for image search showing filter options like date range, mission type (e.g., Sentinel-2-MSI, I2A), and cloud cover to refine the search results.

Select the best image

- Look through the results and pick an image with <5% cloud cover.
- Click on the view options to see its preview and metadata
- Check the Product Info and ensure the image meets the needs.

Figure 7. Page where users can preview the search results by clicking on different icons (eg, view, zoom, add to cart, and download) and review metadata to select the most suitable image.

After unzipping the downloaded file, visualize the data and extract the required bands

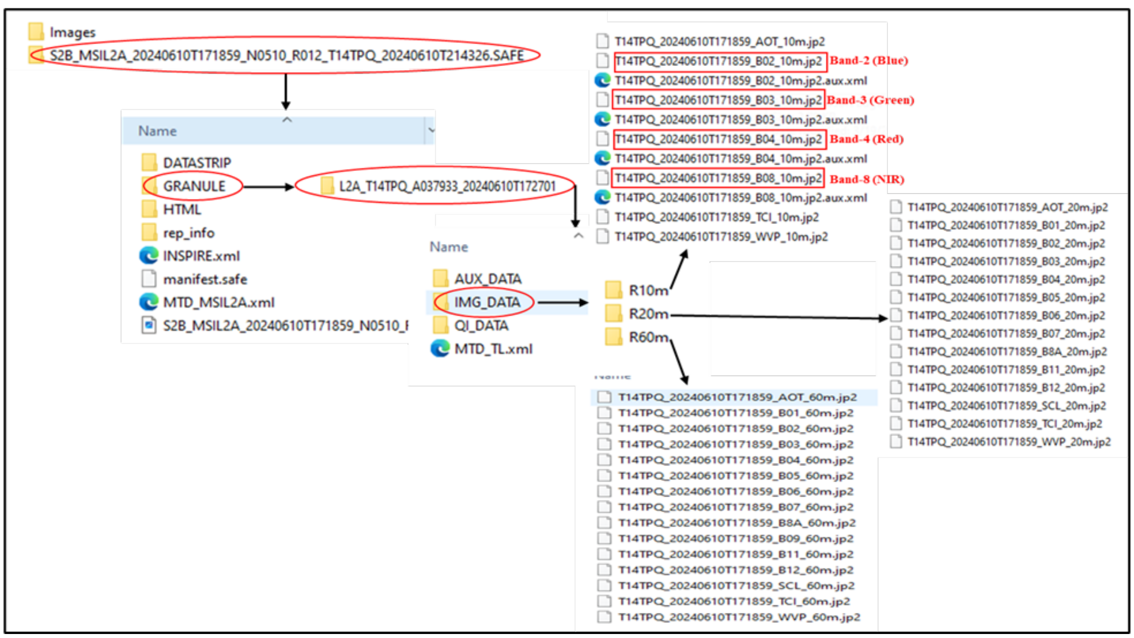

Figure 8. Page to visualize the downloaded image and unzip it to extract the required spectral bands for analysis.

MSI Bands Example

Figure 9. Example to show the results of how Sentinel-2 MSI bands (Red, Green, Blue, NIR, and Red Edge) are combined to generate a true color or false color composite image for vegetation and land surface analysis.

Steps to process Excess Green Index (EGI) using MSI bands

- Load the data: import satellite data (red, green and blue bands) to the QGIS.
- Access the raster calculator: Navigate to the raster calculator tool within QGIS. This tool allows you to perform mathematical operations on raster datasets.
- Enter the EGI formula: In raster calculator insert EGI formula: EGI=2G-(R+B)
- Ensure the order of bands is correct for subtraction.
- Save the result: Designate an output file for your EGI result, preferably saving it as a TIFF file for optimal compatibility.

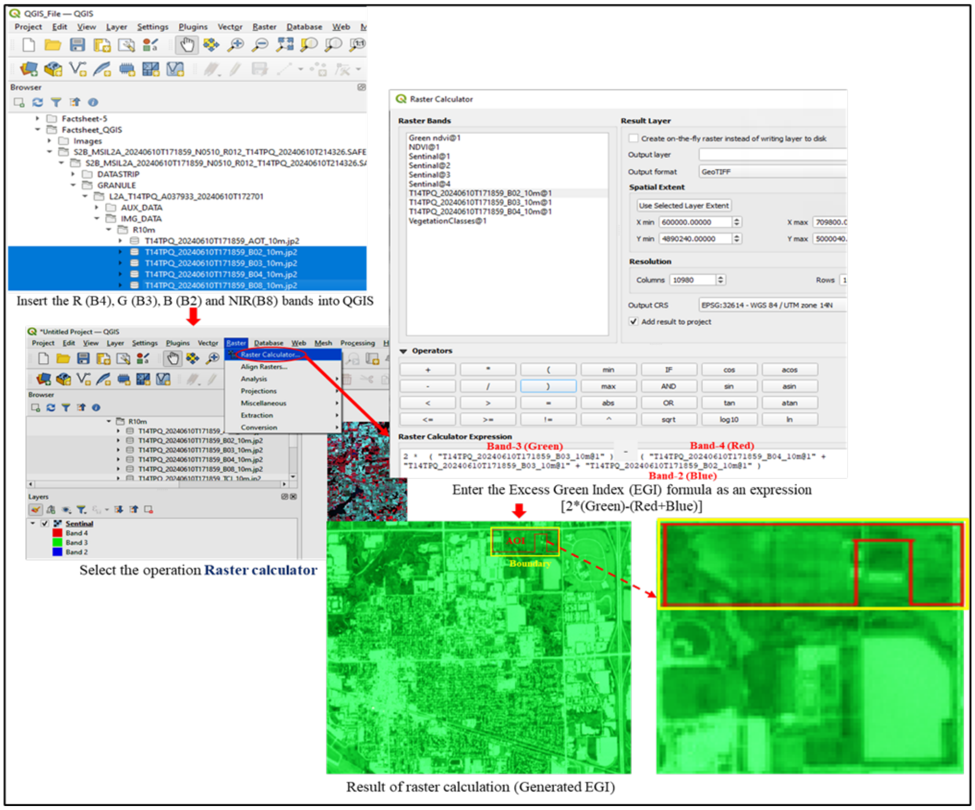

Figure 10. Example to show processing steps for the Excess Green Index (EGI) in QGIS using the raster calculator by applying the EGI formula on MSI bands and saving the output as a TIFF file.

Visualizing the EGI Result in QGIS

Adjust symbology and interpret the results:

Once the EGI calculation is complete, you can adjust the symbology to better visualize the values. Use color ramps to distinguish between crops and weeds based on their greenness. Areas with lower EGI may indicate plant stress. The study area (28+ acres) is located at South Dakota State University (Plant Path North/P1-P4) in Brookings County, South Dakota (coordinates: 44.325482 to 44.323224 N, -96.776982 to -96.768311 E).

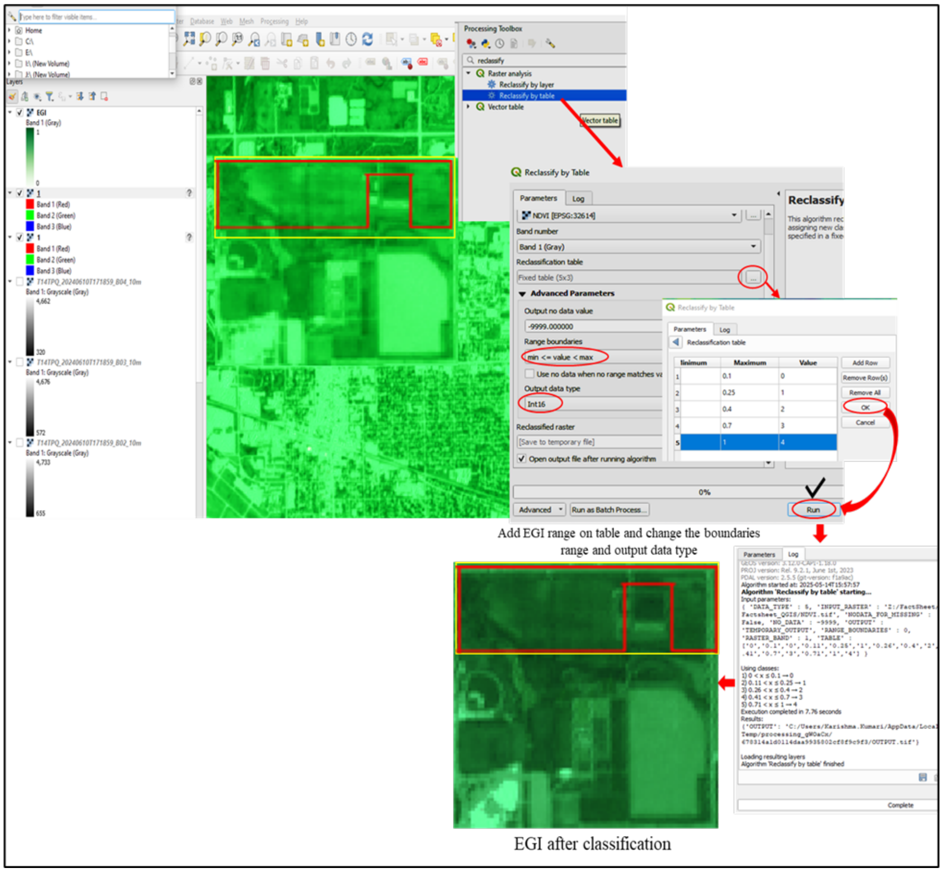

Figure 11. Example of using QGIS to visualize and adjust the EGI results using color ramps to differentiate vegetation health. The study area (28 acres) is located at South Dakota State University (Plant Path North/P1-P4) in Brookings County, South Dakota (coordinates: 44.325482 to 44.323224 N, -96.776982 to -96.768311 E).

Example 2: EGI processed from bands

EGI was derived using red (B4), green (B3) and blue (B2) bands with the formula (commonly used in precise spraying and field analysis):

$$\mathrm{EGI} = 2R - (G + B)$$

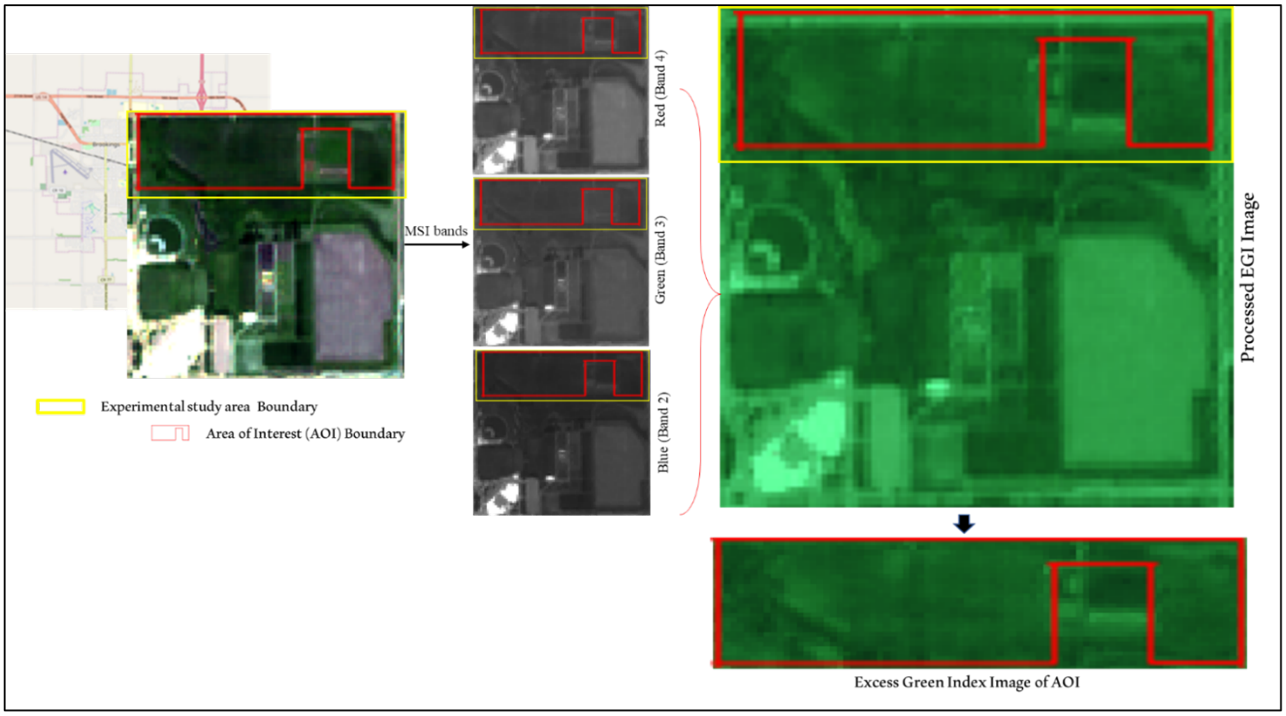

Figure 12. Example showing the results of Sentinel-2 MSI bands (Red, Green, and Blue) after processing using the EGI formula to enhance vegetation detection for the selected AOI.

References

Elspina. A quick tutorial for Sentinel analysis. Space. space.elspina.tech/a-quick-tutorial-for-sentinel-analysis-d5b9092f3212

Copernicus. Copernicus Browser. browser.dataspace.copernicus.eu

GISAgMaps. Course 2B: Satellite Data Processing and Analysis. gisagmaps.org/course-2b/

Correia, R., Duarte, L., Teodoro, A. C., & Monteiro, A. T. (2018). Processing image to geographical information systems (PI2GIS): A learning tool for QGIS. Education Sciences, 8(2), 83. doi.org/10.3390/educsci8020083

Kim, D.-W., Yun, H., Jeong, S.-J., & Kim, H.-J. (2018). Modeling and testing of growth status for Chinese cabbage and white radish with UAV-based RGB imagery. Remote Sensing, 10(4), 563. doi.org/10.3390/rs10040563

gis.stackexchange.com/questions/24861/cropping-raster-layer-using-qgis

hatarilabs.com/ih-en/how-to-represent-sentinel-2-bands-in-a-true-color-image-with-qgis

youtube.com/watch?v=EaC5sQpExjg

South Dakota State University Extension

SOUTH DAKOTA STATE UNIVERSITY®
AGRONOMY, HORTICULTURE AND PLANT SCIENCE DEPARTMENT

P-00342