Smarter Farming Decisions Using ArcGIS and Satellite Imagery

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Introduction

ArcGIS and satellite imagery are powerful tools for collecting and visualizing geographic data, enabling accurate mapping of agricultural data/information, and providing timely updates on field conditions. For example, NDVI (Normalized Difference Vegetation Index) maps can support data-driven decisions in precision agriculture, such as determining where to apply fertilizer, planning irrigation, and predicting crop yields. Farmers, agronomists, researchers, and Extension can make more precise decisions and apply targeted crop input strategies, improving productivity and managing resources more efficiently. This fact sheet provides valuable insights into how these tools can be used to monitor crop performance, assess field conditions, and support better agricultural outcomes.

What is involved in using satellite imagery?

Satellite imagery refers to images of Earth captured by sensors on satellites. These sensors collect data across various bands of the electromagnetic spectrum including the visible bands (i.e., red, green, blue) and invisible bands (i.e., near and far Infrared).

The process is:

1. **Data Collection:** As a satellite passes over an area, its sensors record reflected sunlight and emitted energy from Earth's surface. Different materials (such as plants, soil, water) reflect and absorb light differently in different spectral bands. These differences create unique "spectral signatures" that can be used to identify and determine specific characteristics of the surface (i.e., stage of growth of a crop, type of crop, crop stress status, etc.).

2. **Data Transmission:** The satellite sends the raw data back to ground stations on Earth where it is stored and processed.

3. **Image Processing:** Specialized software processes the raw image data to natural-color images or false-color images. It can also highlight specific features, such as vegetation health or soil moisture spectral indices. The relationship between certain spectral indices, such as NDVI, can reveal additional insights.

4. **Applications in Agriculture:** In farming, satellite imagery can be used for many purposes, such as crop health monitoring, soil condition assessment, crop yield estimation, etc.

Satellite imagery can transform your farm insights!

Practical benefits of using satellite imagery can save you time and money by: (1) reducing chemical use by applying inputs only where needed, (2) spotting stressed crops early and taking corrective action before it is too late, (3) making improved planting, fertilizing, and harvesting decisions based on real-time data, (4) identifying drainage problems or droughty areas quickly, and (5) comparing field performance to get insights on field variability. These benefits will result in increased yields and improved soil and water management.

Satellite images are often processed into tools like the **NDVI (Normalized Difference Vegetation Index)**, a numerical index calculated from the light reflectance in the Red and near-infrared (NIR) spectral bands as:

$$NDVI = \frac{NIR - Red}{NIR + Red}$$

In general, NDVI values are indicative of the health and vigor of vegetation. NDVI applications including monitoring crop health, detecting drought stress, identifying disease in vegetation, can help farmers perform precision agriculture practices. Healthy plants tend to reflect more NIR light and absorb more Red light compared to stressed or unhealthy plants. NDVI values closer to +1 (e.g., 0.72) are likely to indicate healthy, green vegetation while values closer to 0 (e.g., 0.14) tend to indicate stressed vegetation, bare soil, or other non-vegetated surfaces.

Although some may be hesitant about adopting new technology, getting started with satellite imagery is now simple. Providers like Sentinel Hub offer free trials suitable for farms of any size. Many small-holder farmers already use satellite images - often with just a smartphone to identify problems in their fields. Free and open-access Sentinel-2 data are publicly available, supporting a wide range of global research and practical applications in agriculture, environmental monitoring, and more. The Sentinel-2 mission, launched by the European Space Agency (ESA), provides high-resolution multispectral images of Earth's surface through its Multispectral Instrument (MSI). The captured images with different spectral bands, including visible, near-infrared (NIR), and shortwave infrared (SWIR) wavelengths, allow us to observe vegetation health, soil moisture, and crop conditions that are invisible to the human eye.

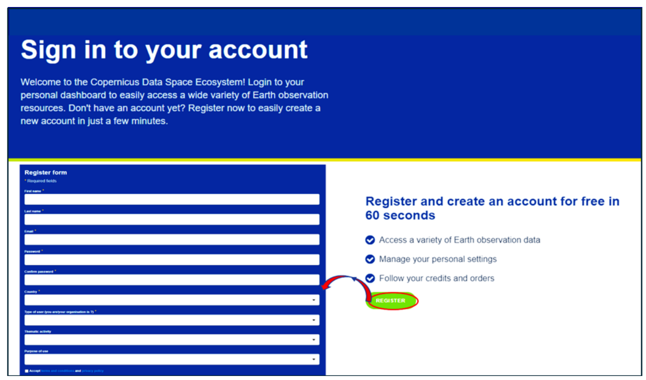
Step-by-Step Guide to Download Sentinel Satellite NDVI Images

1. Visit the Copernicus Open Access Hub website

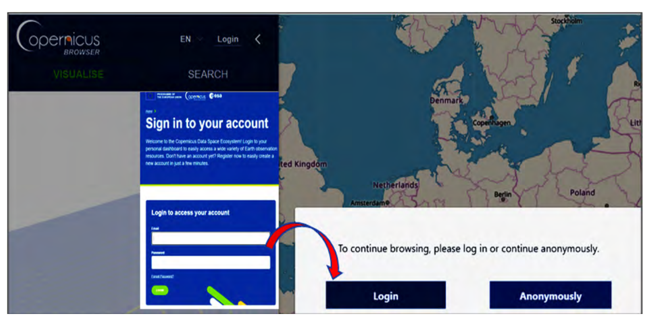
- To download the sentinel satellite images, go to the website by clicking on this link: https://browser.dataspace.copernicus.eu/
- This website provides free access to European Space Agency (ESA) satellite images.

2. Sign-up and log-in

- Click on green color **Resister** option to create an account if you are a new user.
- Fill in your details (name, country, email, password, etc.) on the popped form and create a **username and password**.

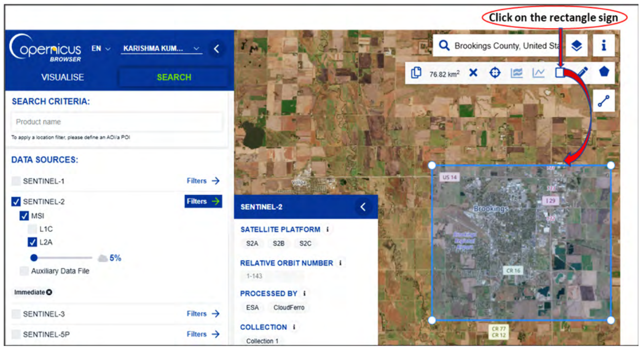


- Check your email for a **confirmation link** and verify your account and return to the website and click on **Log In**. Enter your username and password to enter in the main environment.



3. Choose your area of interest (AOI)

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



4. Search for images

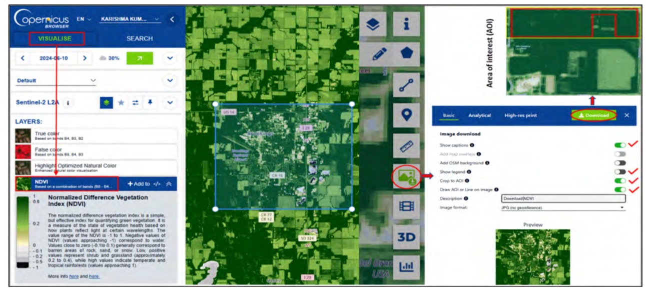
- Click on the **Search** tab in the top menu.
- Use the filters (**Data sources tab**) on the left side of the screen to refine your search:
    - **Time Range**: Select a date range (from and until) to find recent images.
    - **Mission:** Choose Sentinel-2 (NDVI) for land images.
    - **Cloud Cover:**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

5. 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.

6. Visualize and Download the direct NDVI Image

- Click on the Visualize tab to access the NDVI layer option.
- Check the NDVI image while focusing on the Area of Interest (AOI).
- Click on the Gallery icon with the Download symbol.
- Enable all relevant options to ensure high-quality output and select the file format.
- Finally, click on the Download button to save the image.



7. Steps to process indirect NDVI using MSI bands using ArcGIS

The boundary of a field is typically created using Google Earth. Drawing boundaries in Google Earth is straightforward and it also provides high-resolution imagery that allows users to clearly visualize field boundary (Figure 1). Open Google Earth, click on icon “add polygon”, make your boundary on your field, and then save it.

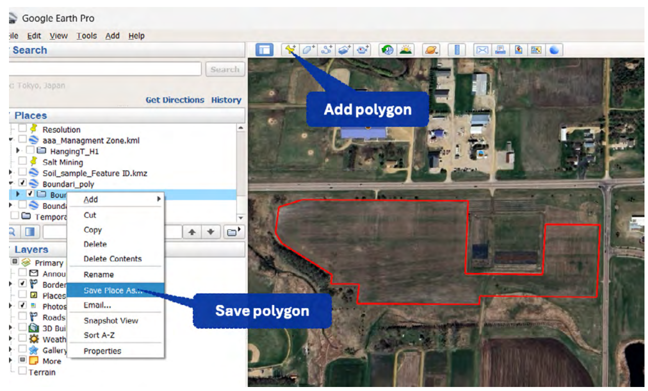


Figure 1. Creating Boundary in Google Earth using “add polygon” option in toolbar.

Load the data: Open ArcGIS Pro and create new project by clicking on map (Figure 2a). Then, Right click on “Map”, and then “add data” (Figure 2b).

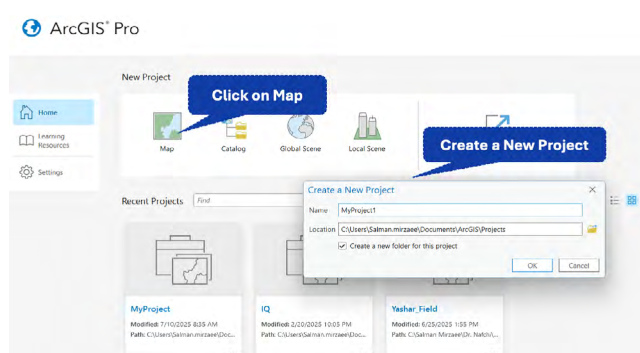


Figure 2a. Open ArcGIS and click on “Map”.

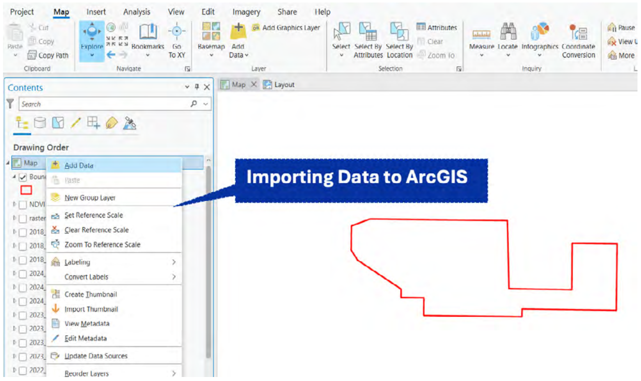


Figure 2b. Then click “add data”

Satellite image bands: Find your Satellite image path and import to the ArcGIS Pro (Figure 3).

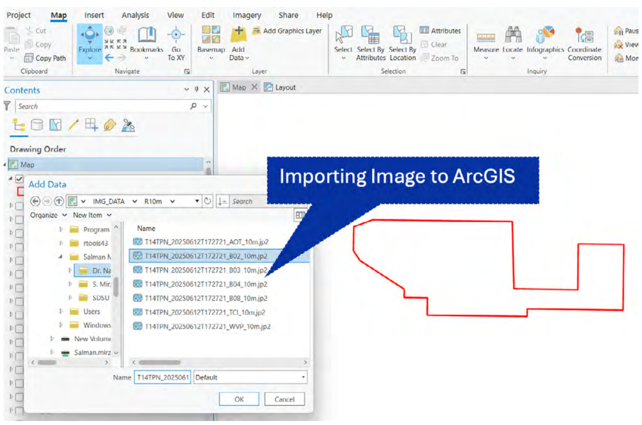


Figure 3. Importing Satellite Image bands into ArcGIS Pro.

Access the raster calculator: Navigate to the raster calculator tool within ArcGIS Pro. This tool allows you to perform mathematical operations on raster datasets (Figure 4).

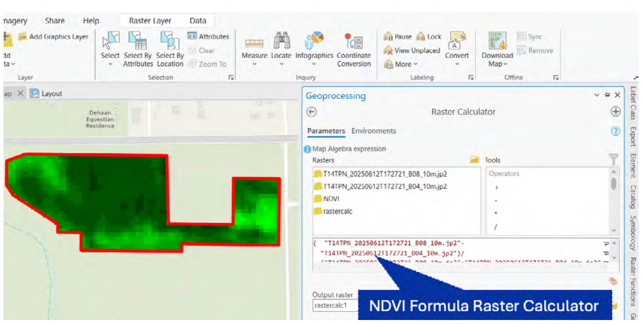


Figure 4. In Geoprocessing open “Raster Calculator” in ArcGIS Pro.

Enter the NDVI formula: First of all, open the Geoprocessing and then search “Raster Calculator”. In the raster calculator, input the NDVI formula using the Red and NIR bands. Ensure the order of bands is correct for subtraction (Figure 5).

The formula for input is: (NIR (Band 8) – Red (Band 4)) / (NIR (Band 8) + Red (Band 4)).

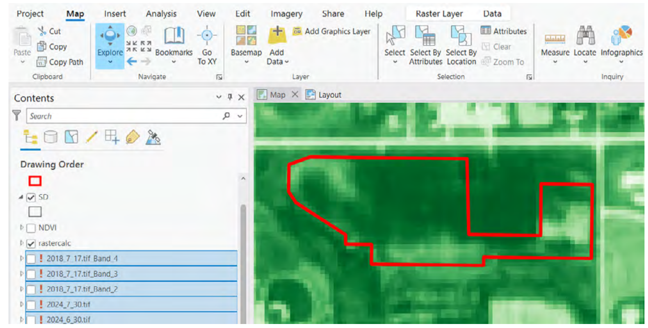


Figure 5. Created an NDVI map in ArcGIS.

Save the result: Designate an output file for your NDVI result, preferably saving it as a TIFF file for optimal compatibility (Figure 6).

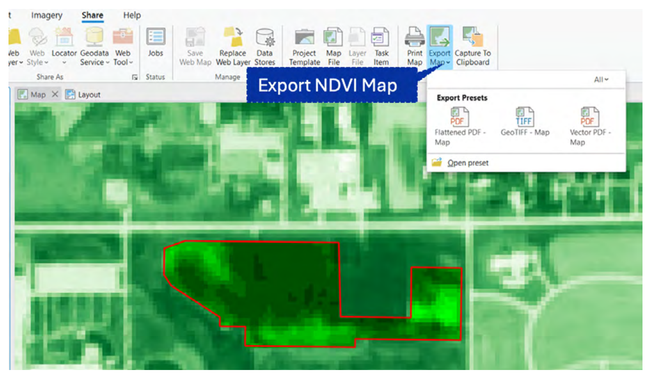


Figure 6. Save the NDVI map using “Share” and “Export Map” in ArcGIS.

Save the result: Designate an output file for your NDVI result, preferably saving it as a TIFF file for optimal compatibility (Figure 6).

8. Visualizing the NDVI Result in ArcGIS Pro

Adjust symbology and interpret the results: Once the NDVI calculation is complete, you can adjust the symbology to better visualize the values (Figure 7). Use color ramps to differentiate between high (healthy vegetation) and low (sparse or no vegetation) NDVI values. Areas with high NDVI values indicate healthy, green vegetation. Low NDVI values, especially those close to -1, often represent water bodies, as water absorbs near-infrared light.

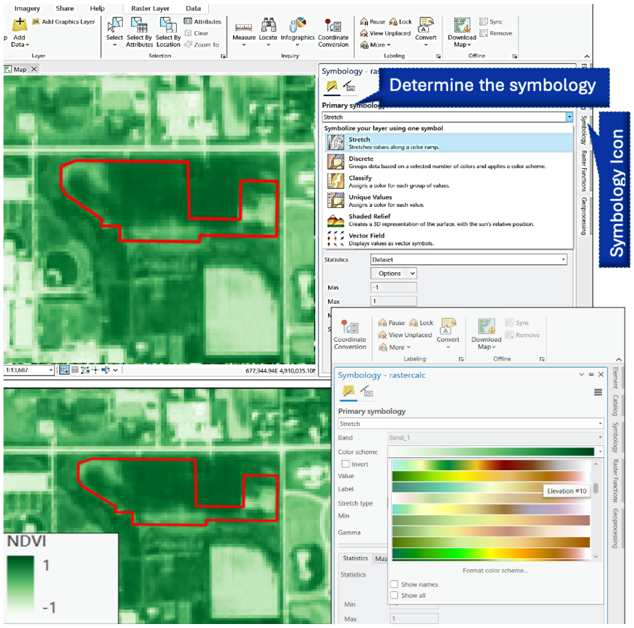


Figure 7. Determining the color scheme of NDVI in ArcGIS Pro.

NDVI for specific field: 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 1: NDVI processed from bands

In this method, the NDVI was derived using the Red (Band 4 of Sentinel-2) and Near Infrared (Band 8 of Sentinel-2) bands with the formula (Figure 8):

$$\mathbf{NDVI = (B8 - B4) / (B8 + B4)}$$

This processed NDVI helped assess the crop health variability across different field management zones.

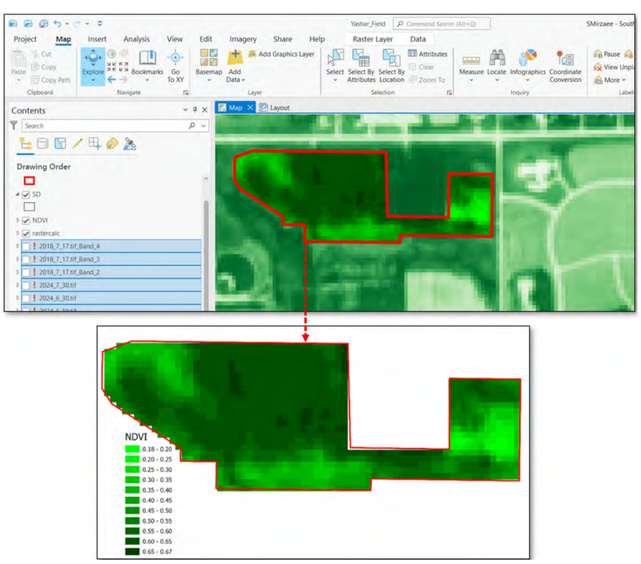


Figure 8. NDVI map created in ArcGIS from Sentinel-2 imagery.

Example 2: Direct downloaded NDVI

NDVI was directly downloaded from Sentinel Hub EO Browser (Figure 9) using pre-processed Sentinel-2 NDVI imagery (10 m resolution).

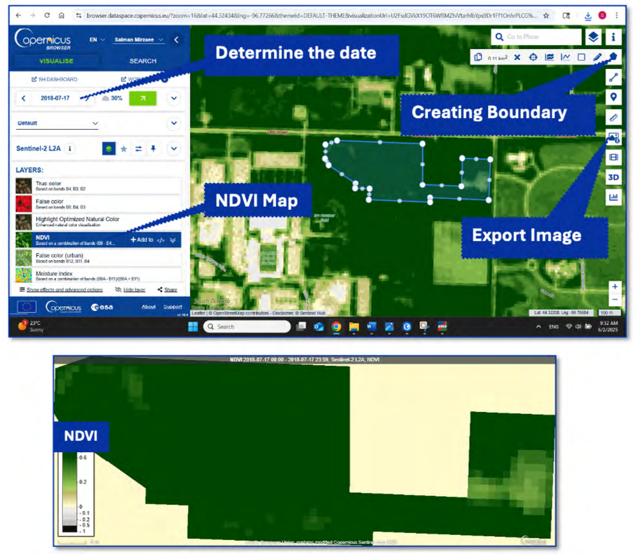


Figure 9. NDVI map was directly downloaded from Sentinel Hub EO Browser.

Question: Why calculate NDVI yourself if you can just download the NDVI map from Sentinel Hub Browser?

Answer: Downloaded NDVI layers are great for quick looks but calculating it will provide real numeric values for analysis, with control over inputs (L2A vs TOA, bands like B8/B8A, resampling, projection, AOI), custom cloud/shadow/snow masking, proper time-series/composites, and reproducible, scalable workflows that integrate with other indices. The example “NDVI processed from bands” is to explain how to derive different indices from Sentinel-2 (e.g., NDVI, EVI, NDWI), not just display a single prebuilt layer.

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