EO AGRI-DATA EXPLORER USER GUIDE

SPACE HUB YORKSHIRE

Contents

Introduction ... 2
Interface ... 3
Accessibility ... 3
Inputs & Options ... 4
Data Interpretation ... 5
Where to learn more ... 8
Frequently Asked Questions ... 9
References ... 11

Introduction

As part of Space Hub Yorkshire's GreenSpace Project, we have produced an app (available here: https://spacehubyorkshire.users.earthengine.app/view/eo-agri-data-explorer) that lets users explore Sentinel 2 satellite data and create examples of how it can be applied to UK agricultural fields. The app outputs a range of different indices depending on the user's preferences, or one of three different image composites. These data can be used to assess the growth state of vegetation, a harvest, surface moisture and flooding, burnt areas, and the presence of bare soil. The information can be outputted as a map overlay within the selected UK field, a graph of index value vs time, or as a data table.

The app automatically pulls Sentinel 2 data for the area of interest during the specified date range, crops the images to either the field or a 500m radius area around the field, removes clouds and cloud shadows (though not snow) from the image and produces maps, timeseries graphs, or tables of data depending on the user's request. The user can request indices or different composite images to be returned.

We do not recommend processing more than 1 year of images at a time, and if difficulties are encountered with long processing times or the app freezing, we recommend reducing the date range. If your browser becomes unresponsive, try waiting once or twice before restarting the app – sometimes a longer processing time causes this reaction from the browser, but it typically eventually completes and shows the requested data.

The app is written in and hosted on Google Earth Engine, and use of the app is governed by Google Earth Engine's terms of service. The GEE code is available here.

Disclaimer*: this app is designed to raise awareness of and teach users about the potential uses of freely available satellite data and to allow users to explore demonstrations of its application in real-world scenarios. It is not meant to be used for commercial purposes and commercial or legal decisions should not be based upon the data it outputs. We do not use the app to sell a product or service, do not endorse specific products relating to the uses here, and receive no compensation from users using the app to explore the data. This app is published as-is and we will not be maintaining it. The terms of using Google Earth Engine services for commercial or government uses are available on the Google Earth Engine website.*

Interface

The app's interface is made up of a map window and a user input panel. The user panel includes:

- two date sliders that the user can input their desired date range to query
- a latitude and longitude coordinate box which can be filed manually or by clicking a location on the map
- A drop-down menu that lets the user select the type of data they'd like to generate and view, and in what format they'd like to view it.

Depending upon the options selected by the user, additional panels may be generated to the right of the standard input panel. These additional panels can be expanded by clicking the icon and can be closed using the "close" button. The map can be cleared at any point by clicking the "clear map" button on the right-hand side of the map panel.

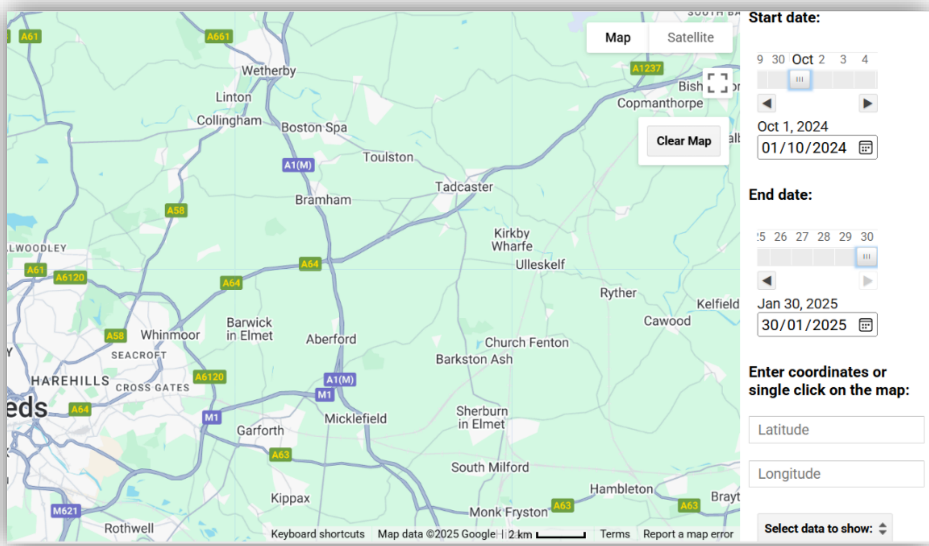
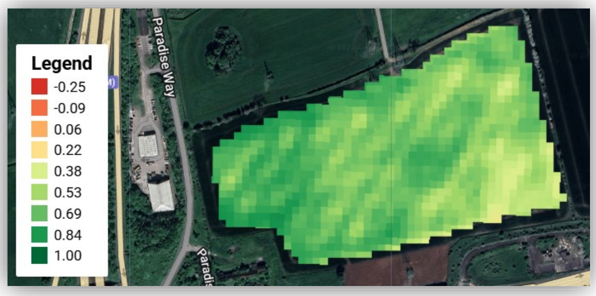


Figure 1 - Image of the app's interface.

Accessibility

The interface offers a "colour accessibility mode" that can be enabled. For single band data, this overrides colour maps and palettes to a colour vision deficiency ("colour blind") friendly palette. For composite images, it increases the gamma to increase the contrast between different colours.



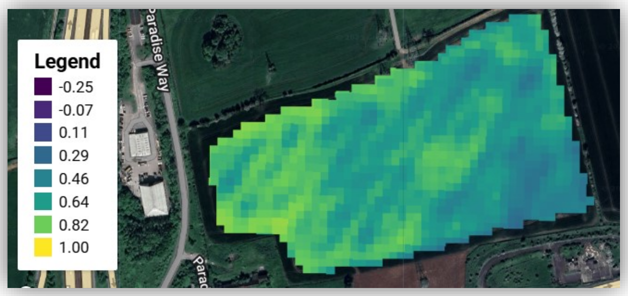


Figure 2 - side-by-side comparison of standard (L) vs colour accessibility mode (R).

Inputs & Options

- **Start date:** a date slider and date selector that lets the user specify the earliest date they'd like data or images from. By default, this is set to the date 4 months before today.
- **End date:** a date slider and date selector that lets the user specify the latest date they'd like data from. By default, this is set to today.
- **Latitude and Longitude:** the user must specify the longitude and latitude of a point inside the field they'd like data from. This field must be within the UK and disclaimer: not all fields are included in the database and some field boundaries may be inaccurate or out of date.
  Longitude and latitude must be given in decimal degrees. The user can use the map (and can pan and zoom) to select a point by single clicking on the map. A red dot should appear and automatically populate the latitude and longitude boxes. Clicking on the map again will remove the selected marker and create a new marker and repopulate the latitude and longitude boxes.
- **Data Selector:** this drop-down menu lets the user select the type of data they'd like to produce and view. It is broken up into 6 different options:
  a. NDVI or Normalised Difference Vegetation Index
  b. NDWI or Normalised Difference Water Index
  c. NDMI or Normalised Difference Moisture Index
  d. BSI or Bare Soil Index
  e. RGB - a true colour composite image
  f. SWIR - a false colour image that uses infrared as one of the colour input channels

The app removes clouds and cloud shadows from the calibrated data before producing the data products listed above. This means that there may be data missing from the field where cloud cover was present. It also means that maps can sometimes have unusual appearances which looks like holes in the data -- this is normal and is simply a product of the cloud cover affecting what can be viewed.

- **View Options:** Selecting options (a) to (d) will cause an additional drop-down menu to appear that lets the user select how they would like to view the data:
  - **Map view**- this creates a map of the chosen index across the field (and specifically only within the boundaries of the field). A drop-down menu appears on the map allowing the user to specify the date they'd like to view. The map may take a short time to render but rendering progress when switching between dates should be visible on the "layers" widget after the initial data processing is complete. The map will also have a legend allowing the user to interpret the map colours to index values. The map can be cleared at any point by clicking the "clear map" button.

- **Plot view** - this creates two graphs, each of which can be expanded by clicking the pop out icon in the top right-hand corner of the new panel. The new panel can be closed by clicking the close button. The two graphs show:

    1. the mean ("average") value of the chosen index across the field over time along with an upper and lower line, representing the standard deviation of the index across the field (with normally distributed data, 68% of the values of the index in the field would lie between these upper and lower lines).

    2. the median value of the chosen index across the field over time. This graph has solid lines above and below showing the 25th and 75th percentile range and dashed lines showing the minimum and maximum values recorded.

- **Data table view** - this creates a new panel containing a data table showing the mean, median, standard deviation, 25th and 75th percentile points, and maximum and minimum values of the selected index across the field over time. This table can be expanded by clicking the pop out button in the top right-hand corner of the data table (it may be difficult to see), and the panel closed by clicking the close button.

- **Average Map View** – this lets the user select whether they'd like a single average map for the whole date range (check the box) instead of the standard map view described above. Every pixel is calculated as the mean of that pixel across all images in the date range. There is no weighting based on time between images.

- **Submit button:** clicking this button submits the data options that the user has selected and begins the data processing. This may take a short time to complete. In some instances, particularly for large fields or long time periods, the processing time is long enough so that the browser pops up saying it has become unresponsive. This isn't typically the case, and by clicking "wait" the data processing can be completed and outputs viewed. If this has happened several times and the data processing has not completed, try reloading the app and/or reducing the data range.

Data Interpretation

Primer on Sentinel 2

This app uses data from the Sentinel 2 mission, which consists of two satellites: Sentinel 2A and Sentinel 2B. Sentinel 2 data is freely available to anyone in the UK via the Copernicus programme [1]. These satellites observe the Earth in 13 different bands[1]. The wavelengths of light (in nm) and how they correspond to Sentinel 2's bands are shown in Table 1. The resolution describes the size of the area of Earth covered by a single pixel.

The observed reflectance[2] in different bands and combinations of bands are sensitive to different properties of the Earth's surface, as different surfaces reflect incoming light differently[3]. Because of this, different false colour images or numerical indices can be created based on how much light is reflected and in which bands.

Table 1 - Sentinel 2 bands and features [2, 3].

Band Number	Description	Wavelength [nm]	Resolution [m]
1	aerosols	429 – 457	60
2	blue	451 – 539	10
3	green	538 – 585	10

[1] A band in this context means a wavelength range that the sensor observes in.
[2] Reflectance means the proportion of incoming light that is reflected off a surface
[3] See https://seos-project.eu/remotesensing/images/Reflexionskurven.jpg for an example.

4	red	641 – 689	10
5	red edge	695 – 715	20
6	red edge	731 – 749	20
7	red edge	769 – 797	20
8	near infra-red	784 – 900	10
8a	narrow near infra-red	855 – 875	20
9	water vapour	935 – 955	60
10	short wave infra-red cirrus	1365 – 1385	60
11	short wave infra-red 1	1565 – 1655	20
12	short wave infra-red 2	2100 – 2280	20

In this section, this guide gives a brief overview of the meaning and utility of the different data options in this app and the next section will provide a range of links and tools that you can use to learn more.

RGB Composite

This is a true colour image. Three bands are selected from the Sentinel 2 data, corresponding to the red, blue, and green channels (Band 4, Band 2, Band 3 respectively [2]). All three bands have a 10m resolution, meaning that each pixel corresponds to an area approximately 10m x 10m in size. If you look at the satellite view basemap and the RGB Composite option, you'll see very similar colouring, but blurrier due to the lower resolution of sentinel 2 vs the Google Earth Engine basemap.

SWIR Composite

This is a false colour composite, where the RGB channels of an image (which would normally correspond to red-green-blue) are assigned to bands 12, 8A, and 4 instead [4]. The result is an image which highlights greenery (in green), water appears dark, and bare soil and built-up areas appear brown. The denser and greener the vegetation, the darker green the image portion will appear. Burnt areas will stand out in this composite when compared to earlier unburnt images. This band will have a slightly lower resolution of 20m per pixel.

"Agriculture" Composite

This image is produced from a combination of bands 11, 8, and 2 [4]. In this composite image, dense and healthy vegetation appears dark green, water appears dark, and similarly to the previous composite, burnt areas will stand out when compared to earlier unburnt images. This band's resolution will be 20m per pixel. This composite may be more useful at highlighting healthy/unhealthy vegetation than the SWIR composite above, but both have their strengths.

Normalised Difference Vegetation Index (NDVI)

Normalised difference vegetation index, or NDVI, is a measurement of how vegetated a patch of land is. It is calculated by comparing the reflectance in the red (band 4 in Sentinel 2 data) and the infra-red (NIR, band 8 in Sentinel 2 data):

$$\mathrm{NDVI} = \frac{\mathrm{NIR} - \mathrm{Red}}{\mathrm{NIR} + \mathrm{Red}} = \frac{\mathrm{Band\ 8} - \mathrm{Band\ 4}}{\mathrm{Band\ 8} + \mathrm{Band\ 4}}$$

The calculated value will lie between -1 and 1. Green leaves scatter near infra-red but chlorophyll strongly absorbs red light, which is different to other types of surfaces like bare soil or land. This gives vegetation a positive NDVI value. Higher positive values are indicative of greener, denser, healthier vegetation, while bare soil will have NDVI values close to zero, meaning its reflectance is similar in both bands [5]. Water will have NDVI values below -0.15.

Normalised Difference Moisture Index (NDMI)

Normalised difference moisture index, or NDMI, measures the water content of a canopy and therefore can be used as a measurement of water stress in crops. NDMI is calculated by comparing the reflectance of two infra-red wavelength bands (Near infra-red, NIR - band 8 in Sentinel 2, and short wave infra-red, SWIR - band 11 in Sentinel 2:

$$\text{NDMI} = \frac{\text{NIR} - \text{SWIR}}{\text{NIR} + \text{SWIR}} = \frac{\text{Band 8} - \text{Band 11}}{\text{Band 8} + \text{Band 11}}$$

NDMI values range between 1 and -1. Typically, lower values represent lower water content, and therefore crops under water stress, and higher values represent high water content [6, 7]. High NDMI values can be indicative of waterlogging. The value for NDMI is also affected by the canopy density itself – for example, a particular value of NDMI can indicate either a lower density canopy with lower water stress or a higher density canopy with a higher water stress, so some interpretation of these values in the context of the crop is needed.

Normalised Difference Water Index (NDWI)

Normalised difference water index, or NDWI, is used to highlight the presence of a water body and variations in its water content. Sometimes the term NDWI is used to refer to what we call NDMI in this guide, but they have very different responses and interpretations, so it is important to differentiate the two. NDWI is calculated by comparing the intensities of the green (band 3 in sentinel 2) and near Infrared (NIR, band 8) wavelengths:

$$\text{NDWI} = \frac{\text{Green} - \text{NIR}}{\text{Green} + \text{NIR}} = \frac{\text{Band 3} - \text{Band 8}}{\text{Band 3} + \text{Band 8}}$$

The value of NDWI ranges from -1 to +1, and water bodies have values greater than 0.3-0.5 [8, 9]. Lower positive values can be indicative of flooding, and negative values show the absence of a surface water body (ie dry ground, vegetation etc).

Bare Soil Index (BSI)

Bare soil index, or BSI, is used to identify regions of bare soil. There are several versions of a bare soil index used in the literature, most notably one that uses the SWIR1 (Band 11) band instead of the SWIR2 (Band 12) band as we use here – both should work, depending upon local land conditions, but sensitivity and performance can vary between the two. In this app, the BSI combines information from the short wave infra-red 2 band (SWIR2, Band 12) with the near infra-red (NIR, Band 8), red (Band 4), and blue (Band 2):

$$\text{BSI} = \frac{(\text{SWIR2} + \text{Red}) - (\text{NIR} + \text{Blue})}{(\text{SWIR2} + \text{Red}) + (\text{NIR} + \text{Blue})} = \frac{(\text{Band 12} + \text{Band 4}) - (\text{Band 8} + \text{Band 2})}{(\text{Band 12} + \text{Band 4}) + (\text{Band 8} + \text{Band 2})}$$

Values for BSI range between -1 and +1. High values of BSI indicate a high likelihood of bare soil, but care should be taken as buildings and other built-up areas can also give high values of BSI. The exact threshold for bare soil depends on location, soil, and crop type but typically higher positive values are likely to correlate with bare soil and negative values with non-bare soil [10, 11, 12].

Green Chlorophyll Index (GCI)

The Green Chlorophyll Index (GCI) is used as an indicator of the chlorophyll content (and nitrogen content) of a canopy. GCI is calculated using the ratio of the reflectance in Band 8 and Green (Band 3):

$$\text{GCI} = \frac{\text{NIR}}{\text{Green}} - 1 = \frac{\text{Band 8}}{\text{Band 3}} - 1$$

The GCI is one of two chlorophyll indices we have implemented. The GCI is applicable to wide range of crop types but may be less sensitive than the red edge index below. Low values, close to zero, indicate low chlorophyll content, high values indicate high chlorophyll content [13, 14, 15].

Red-Edge Chlorophyll Index (RECI)

The Red-Edge Chlorophyll Index (RECI) is also used as an indicator of the chlorophyll content (and nitrogen content) of a canopy. RECI is calculated using the ratio of the reflectance in the near infra-red (NIR, Band 8) and red edge (Band 5):

$$\text{RECI} = \frac{NIR}{Red\ Edge} - 1 = \frac{Band\ 8}{Band\ 5} - 1$$

The RECI is one of two chlorophyll indices we have implemented. The RECI is more sensitive than the GCI above but may not be as widely applicable. Low values, close to zero, indicate low chlorophyll content, high values indicate high chlorophyll content [13, 14, 15].

Where to learn more

Sentinel 2 mission

- https://sentiwiki.copernicus.eu/web/s2-mission - Sentinel 2 mission pages. This and related pages include detailed information about the mission, satellite, sensors, and data.

Earth Observation Training

- NASA Applied Remote Sensing Training (ARSET): https://appliedsciences.nasa.gov/what-we-do/capacity-building/arset - a free training programme provided online or in-person, covering a range of remote sensing topics including agriculture-specific remote sensing and data processing.
- Royal Institute of Navigation Space Applications Learning Hub (free until March 31, 2025) https://rin.org.uk/page/SALHUBTraining - a range of courses including EO data processing and interpretation.
- Copernicus Research and User Support Service: https://eo4society.esa.int/resources/copernicus-rus-training-materials/ - free training materials provided by the EO4Society programme to support the uptake of Copernicus data.

Spectral indices

The references cited in the previous section contain additional information on the specific indices used in this app. For additional, broader information on indices and their applications:

- https://gisgeography.com/sentinel-2-bands-combinations/ - an overview of the most common band combinations and spectral indices and how they can be interpreted.
- https://eo4geocourses.github.io/IGIK_Sentinel2-Data-and-Vegetation-Indices/#/ - a short training course on the use of vegetation (spectral) indices with Sentinel 2 data.
- https://custom-scripts.sentinel-hub.com/custom-scripts/sentinel/sentinel-2/ - a community-provided repository of code and scripts that can be used to help process sentinel 2 data for a variety of indices (and other applications).
- https://eos.com/make-an-analysis/agriculture-band/ - a description of a range of agriculturally useful bands and how they work.

There are many other organisations that provide information about some or all of the spectral indices within this app, including commercial companies who provide more sophisticated and precise data than that provided within this app – these can also be an excellent source of information.

Sentinel 2 data access

- Copernicus Browser – this graphical user interface lets the user interact with and download datasets and displays a variety of pre-processed data (e.g. some indices, scene classifications etc). For most cases, the Level 2A data (surface reflectance) rather than Level 1C (top of atmosphere) should be used.

- Sentinel-2 | Copernicus Data Space Ecosystem – more detailed information and direct links to data and documentation.
- Google Earth Engine: Sentinel-2 Datasets in Earth Engine | Earth Engine Data Catalog | Google for Developers – documentation for Sentinel 2 data use within the Google Earth Engine platform.

Free software to process EO Data

Note that EO data, including Sentinel 2 data, can be very large and can take a lot of processing if working locally rather than on a cloud system.

- SNAP - https://step.esa.int/main/download/snap-download/
- QGIS - https://qgis.org/
- Google Earth Engine (free only for teaching and non-commercial use) - https://earthengine.google.com/

Frequently Asked Questions

The app causes my browser to freeze – is it broken?

No – processing the data and computing the requested index or composite happens in real time on the fly and this can take a little time to complete depending on the date range requested. Try clicking "wait" rather than reloading the app and seeing if it completes. If after "waiting" several times the processing still hasn't completed, try reloading the app and/or reducing the date range requested. We do not recommend trying to process more than one year of data at once.

I've displayed a map from a specific day, but the map has gaps or an odd shape – what is happening?

The app automatically identifies clouds and cloud shadows using the Cloud Score+ dataset [16, 17] and removes the contaminated data. The app does not interpolate or attempt to "fill in" the data, so the removal of clouds and shadowed data can leave large gaps in the data or maps that have strange shapes.

Why is there sometimes a large gap in date coverage?

Like the above, the app detects and removes data contaminated by clouds and shadows. Particularly when restricting to data within a specific field, there might be several weeks or even a month pass without a clear view of the field. If there is no uncontaminated data available for a specific date, that date is not displayed in the list.

Can I request the addition of extra indices or features?

At the current time we are not developing this app beyond the features described here. If you are interested in pursuing the use of or trial of satellite data for a particular purpose, get in contact with Space Hub Yorkshire or your local space cluster and they can introduce you to relevant organisations and support you.

Can I use the app for profit or sell the data it outputs?

No – in its current format, this app can only be used according to the Google Earth Engine terms of service which can be found on Google Earth Engine's website. This app was created and approved for use as a training and outreach tool.

I have a question that isn't answered here!

Get in touch with Space Hub Yorkshire at spacehubyorkshire@leeds.ac.uk with your question and someone will get back to you.

References

[1] Copernicus Dataspace Ecosystem, “Sentinel 2,” [Online]. Available: https://dataspace.copernicus.eu/explore-data/data-collections/sentinel-data/sentinel-2.

[2] Copernicus, “Sentiwiki - Sentinel 2,” [Online]. Available: https://sentiwiki.copernicus.eu/web/s2-mission.

[3] Freie Universitat Berlin, “RESEDA Course - Sentinel 2,” [Online]. Available: https://blogs.fu-berlin.de/reseda/sentinel-2/.

[4] Sentinel Hub Scripts, “Simple RGB Composites (Sentinel-2),” [Online]. Available: https://custom-scripts.sentinel-hub.com/custom-scripts/sentinel-2/composites/.

[5] U.S. Department of Agriculture, Foreign Agricultural Service, “Normalized Difference Vegetation Index (NDVI),” [Online]. Available: https://ipad.fas.usda.gov/cropexplorer/Definitions/spotveg.htm.

[6] EOS Data Analytics, “NDMI (Normalized Difference Moisture Index),” [Online]. Available: https://eos.com/make-an-analysis/ndmi/.

[7] Agricolus, “NDVI and NDMI vegetation indices: instructions for use,” [Online]. Available: https://www.agricolus.com/en/vegetation-indices-ndvi-ndmi/.

[8] EOS Data Analytics, “How to calculate NDWI,” [Online]. Available: https://eos.com/make-an-analysis/ndwi/.

[9] Sentinel Hub, “NDWI Normalized Difference Water Index,” [Online]. Available: https://custom-scripts.sentinel-hub.com/custom-scripts/sentinel-2/ndwi/.

[10] A. Rikimaru, P. Roy and S. Miyatake, “Tropical forest cover density mapping,” *Tropical Ecology,* vol. 43, no. 1, pp. 39-47, 2002.

[11] S. Diek, F. Fornallaz, M. E. Schaepman and R. De Jong, “Barest Pixel Composite for Agricultural Areas Using Landsat Time Series,” *Remote Sensing,* vol. 9, no. 12, p. 1245, 2017.

[12] M. Sebela, “Barren Soil Script,” Sentinel Hub, [Online]. Available: https://custom-scripts.sentinel-hub.com/custom-scripts/sentinel-2/barren_soil/.

[13] J. Clevers and A. Gitelson, “Using the red-edge bands on Sentinel-2 for retrieving canopy chlorophyll and nitrogen content,” *European Space Agency, (Special Publication) ESA SP,* vol. 707, 2012.

[14] Hiphen Agricultural Imaging Solutions, “Vegetation Indices for Chlorophyll (CI – MTCI – NDRE – ND705 – ND550 – mNDblue),” [Online]. Available: https://www.hiphen-plant.com/vegetation-indices-chlorophyll/.

[15] EOS Data Analytics, “Chlorophyll Index In Agriculture,” [Online]. Available: https://eos.com/make-an-analysis/chlorophyll-index/.

[16] V. J. Pasquarella, “Cloud Score+ S2_HARMONIZED V1,” Google Earth, [Online]. Available: https://developers.google.com/earth-engine/datasets/catalog/GOOGLE_CLOUD_SCORE_PLUS_V1_S2_HARMONIZED.

[17] V. J. a. B. C. F. a. C. W. a. R. W. J. Pasquarella, “Comprehensive quality assessment of optical satellite imagery using weakly supervised video learning,” in *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition*, 2023.

Supported by