

GIS and Habitat Management (ACBA 7005)

Fundamentals of Remote Sensing

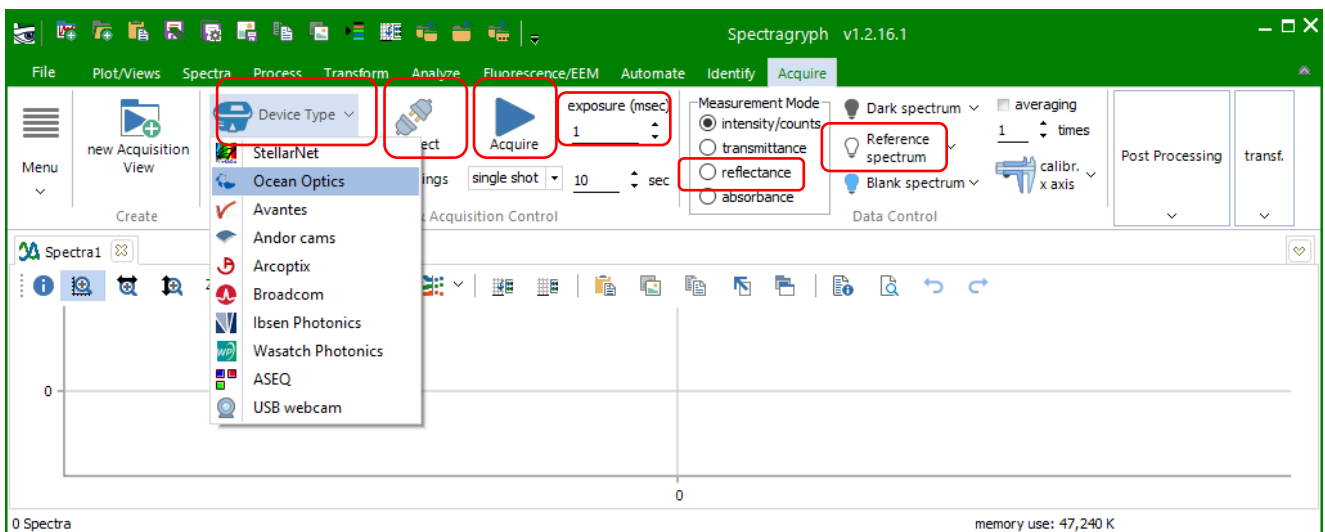
Aim

In this session we will be exploring the concepts of remote sensing, predominantly through Earth Observation (EO) sensors. We will develop an understanding of the core principles of remote sensing, including the different resolutions they operate at, including spatial, temporal, and spectral. This will include two practicals, one using a spectrometer to visualize spectral signatures, and the other using open-source EO data to demonstrate landscape-scale habitat monitoring. This will require access to open-source GIS software QGIS, and a free online account with EO Browser.

Activity 1 – Using a spectrometer to capture spectral profiles

In this first activity, we will be using a spectrometer to capture spectral profiles of different substances / materials, in the visible to near-infrared wavelengths of the electromagnetic spectrum.

By using the contact probe, connected to the Ocean Optics Spectrometer via fibre optic cable, the user can visualise the unique spectral response (reflectance at each electromagnetic wavelength) of the material being analysed. The independent light source provides the active illumination, and once this is calibrated using the reference white panel, the contact probe can be placed against sample targets and the reflectance captured. The open-source software being used, Spectragryph (<https://www.effemm2.de/spectragryph/>) requires a licence beyond the trial version, but can be used to visualise the reflectance curve, and capture multiple spectra for comparison.



Steps for using the spectrometer:

- 1) Ensure the light source is on and connected to the contact panel
- 2) Attach the Ocean Optics fibre optic cable to the contact panel
- 3) Ensure the Spectrometer is connected to the laptop via USB

On the 'Acquire' tab in SpectraGryph:

- 4) From the 'Device Type' dropdown, select Ocean Optics
- 5) Select the 'Connect' icon to connect to the device
- 6) Increase the exposure in seconds (to at least 50)
- 7) Using the white reference panel initially, select 'Acquire'
- 8) Select this as the 'Reference Spectrum' (white light bulb icon)
- 9) Change the 'Measurement Mode' to 'reflectance'
- 10) Begin acquiring spectra of other objects e.g. leaf, plastic, etc. using the 'Acquire' button for each new sample
- 11) To view multiple samples on the same graph, change the settings from 'Single Shot' to 'Additive'

Activity 2 – Landscape-level habitat monitoring on forest disturbance from mining

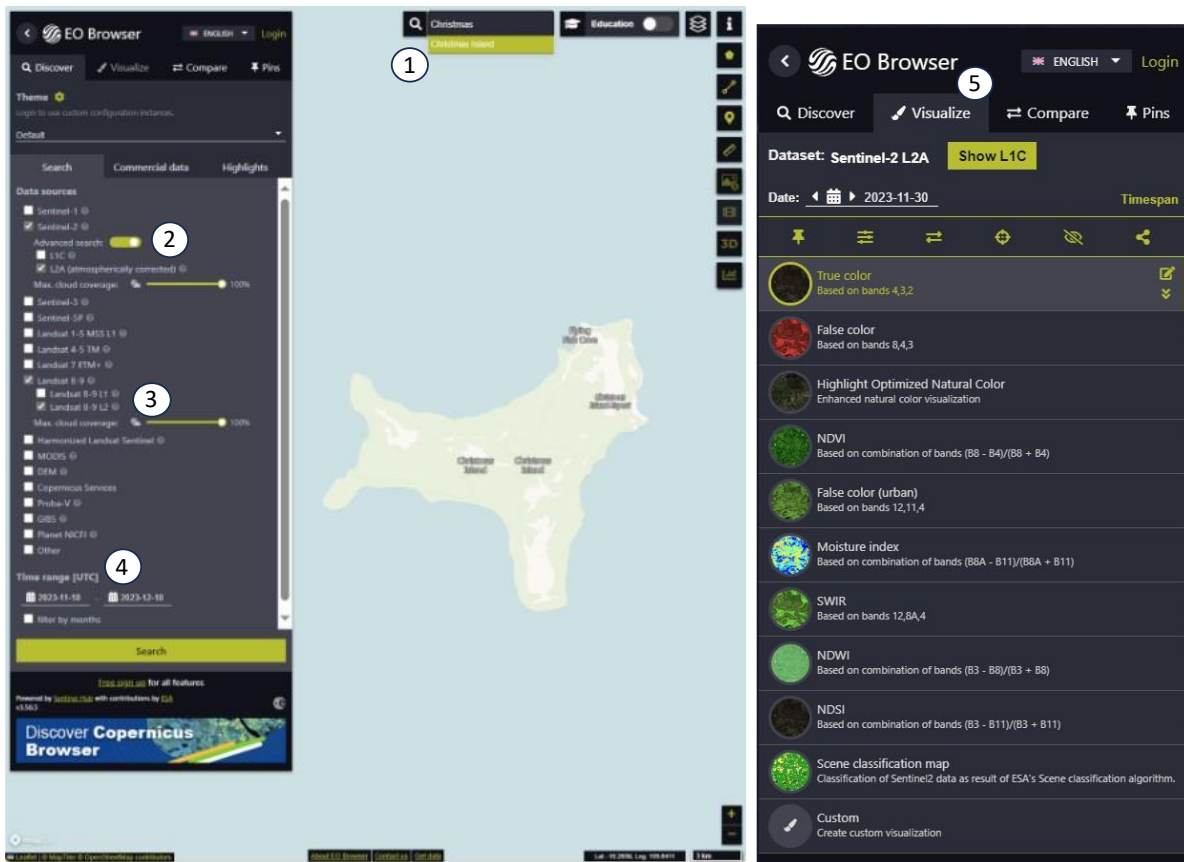
In this second activity, we will be using freely available multi-spectral EO imagery from Sentinel-2, made available via ESA's Copernicus's EO Browser (<https://apps.sentinel-hub.com/eo-browser/>) or Copernicus Browser (<https://browser.dataspace.copernicus.eu/>). While you will not be required to download data yourself directly from either of these providers today in order to carry out the practical, you are welcome to create a free account with both. Note the following:

- Sentinel Hub's EO Browser is a third party provider that provided an online archive delivery and visualisation service for EO providers including Copernicus, but at the time of this practical, Copernicus are in the process of providing their own provision service via:
- Copernicus Browser, which is comparable in capability to EO Browser, but only provides ESA products (at this time).
- The former only provides limited access to customer-specified bespoke sub-sets of imagery, whereas the latter provides access to the raw image tiles, which is essential for quantitative robust temporal analysis.
- Therefore, if doing any quantitative analysis, use Copernicus Browser.

The aim of this exercise is to utilise Sentinel-2 data to monitor for land cover disturbance, mostly from mining activity in the islands forested environment.

2.1 Sourcing EO data

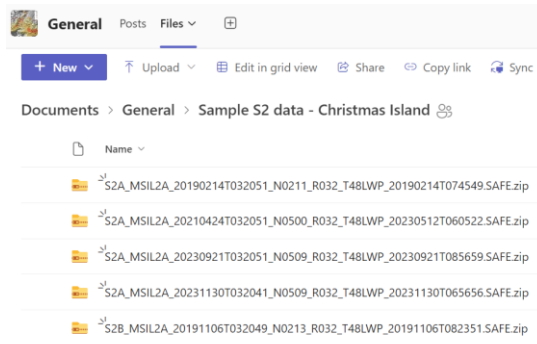
Firstly, we are going to explore the data archive available for the example location of Christmas Island, using Sentinel-Hub's EO Browser.



- 1) Use the Search function to search for 'Christmas Island'
- 2) Select 'Advanced search' for Sentinel-2 and set an appropriate cloud threshold
- 3) Select 'Landsat 8-9' and set an appropriate cloud threshold
- 4) Set a date range and then select 'Search'
- 5) Visualise dates to see them in composites (including RGB) and indices e.g. NDWI.

Now, review the imagery available. Note that if the cloud cover threshold is high (i.e. if you set it at 90%, up to 90% of the scene can be covered in cloud) you will have a lot of results, but most of them will have poor visibility of the Earth's surface.

In the ACBA7005 Teams channel "GIS and Habitat Management_GRP", navigate to the Files tab, and under Documents > General there is a folder called "Sample S2 data - Christmas Island". Within this folder there are several Sentinel-2 images from the same location (tile). Download at least two of these. 06-11-2019 and 21-09-2023 are recommended dates.



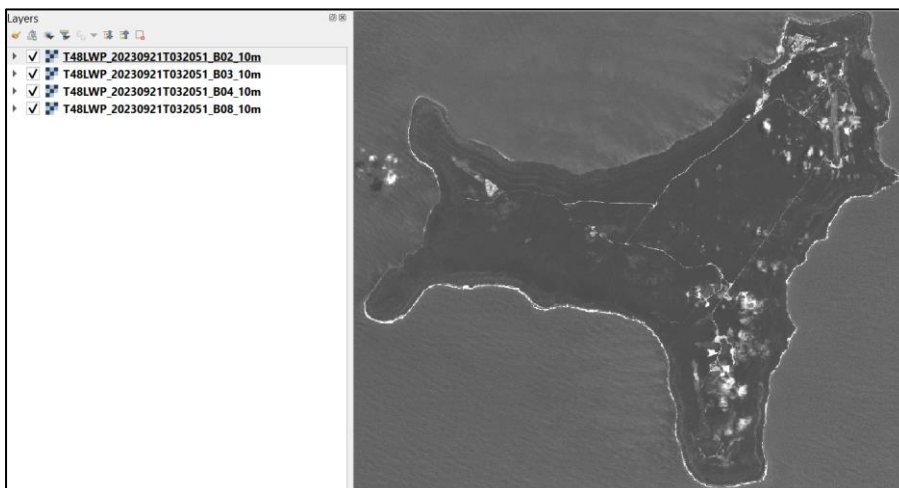
These full scene acquisitions were downloaded from Copernicus Browser, and represent analytics-ready, atmospherically corrected (Level-2) products.

2.2 Visualising Sentinel-2 data in QGIS

There are two ways to visualise this data in QGIS:

- 1) Drag the compressed .SAFE file into QGIS Map View box or Layers panel
 - OR -
- 2) Extract the data and view specific bands
 - a. Extract the .SAFE compressed file (best to use 7-Zip 'Extract here' option – note, depending on where you saved the downloaded folder, the full filepath may exceed the 255 character length, so you may need to move the compressed file to a root location e.g. Desktop)
 - b. Navigate to the 'IMG_DATA' folder
 - c. 'S2X_XXXXXX.SAFE' > 'GRANULE' > 'L2A_XXXX' > 'IMG_DATA'
 - d. Explore the contents of the different pixel resolution folders (10, 20, 60)
 - e. Drag and drop the R10 JP2 files into QGIS Layers panel or Map View.

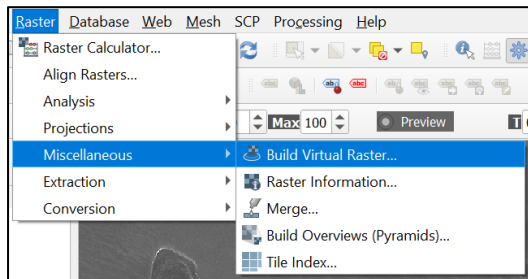
The latter method is preferred. Each band will then be displayed as an individual layer, each in greyscale (see below figure):



While you can use the 'Identify' tool () to interrogate pixel values, visualising spectra is made easier if the bands are stacked.

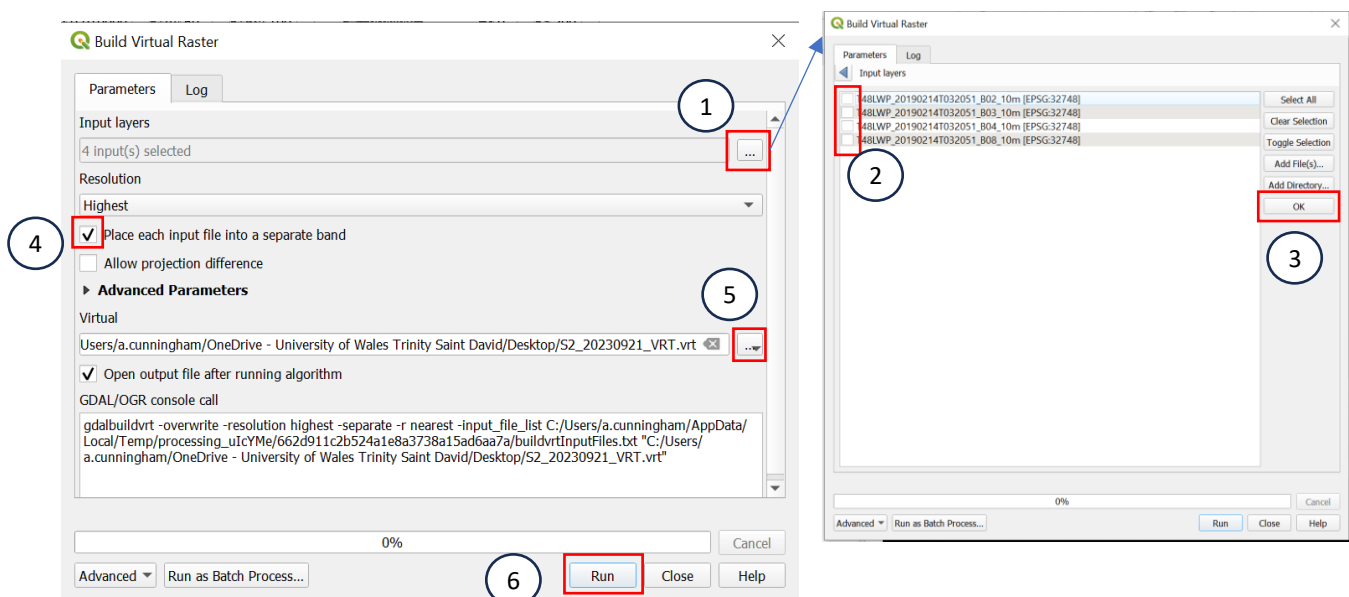
To stack the bands, we will use a virtual raster. This creates a text file which reads each band in using its filepath, rather than duplicating the data.

Create a Virtual Raster



Select the 'Build Virtual Raster' function via:

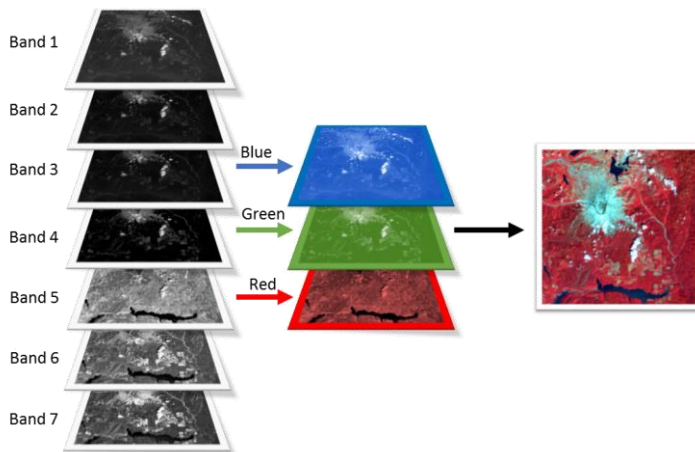
Raster > Miscellaneous > Build Virtual Raster



1. Select the three dots icon to the right of the 'Input layers' input section
2. In the 'Input layers' window, select the layers you wish to include in the VRT using the tickbox icons to the left of each filename
3. Select OK (not Run)
4. Back in the 'Build Virtual Raster' window, select the 'Place each input file into a separate band' tick box option.
5. Specify the output filename and filepath via the three dots icon to the left of the 'Virtual' input box. Ensure to use an appropriate file name that indicates the file contents.
6. Select 'Run'

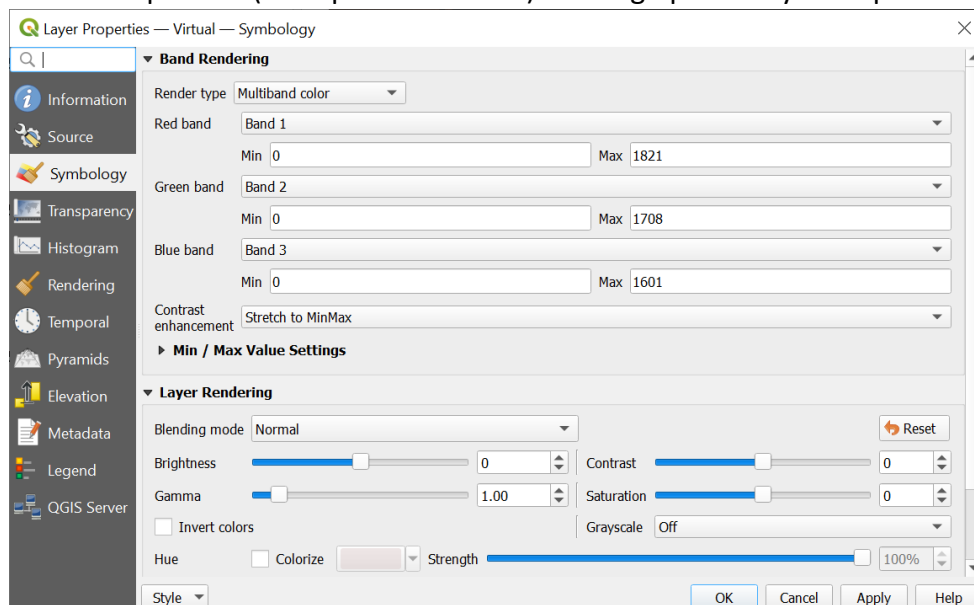
The output of the previous process will be a new VRT file added into the Map View layer, which is a multi-band layer as opposed to a single band file.

This VRT can be viewed as a multi-band composite layer, which can be viewed in RGB via a computer display.



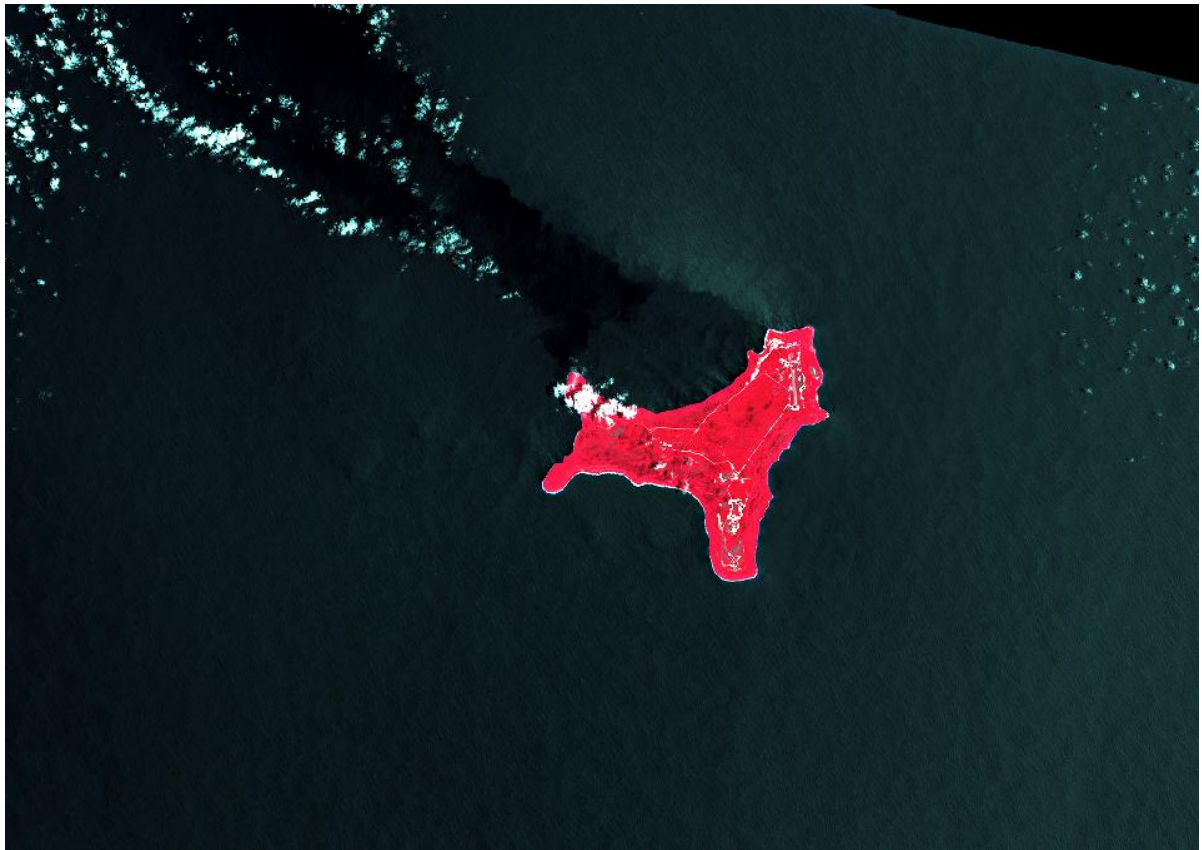
To visualise different composites, change the symbology of the new VRT using the following:

- 1) Right click on the new VRT layer in the Layers panel
- 2) Select 'Properties' (last option in the list) to bring up the 'Layer Properties' window:



- 3) Select the 'Symbology' tab
- 4) The default Render type for a multi-band file is 'Multiband color', if not, this should be selected.
- 5) Modify which band is in each of the respective Red, Green, and Blue bands

- 6) Suggestion: To achieve a false-colour composite which emphasizes vegetated vs non-vegetated surfaces, select the 4th, 3rd, and 2nd, band in Red band, Green, band and Blue band respectively.

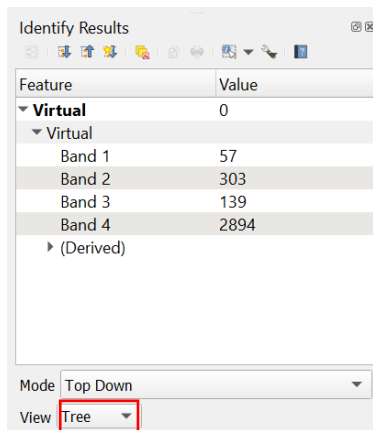


Now that the multi-band raster is ready, spectra can be viewed.

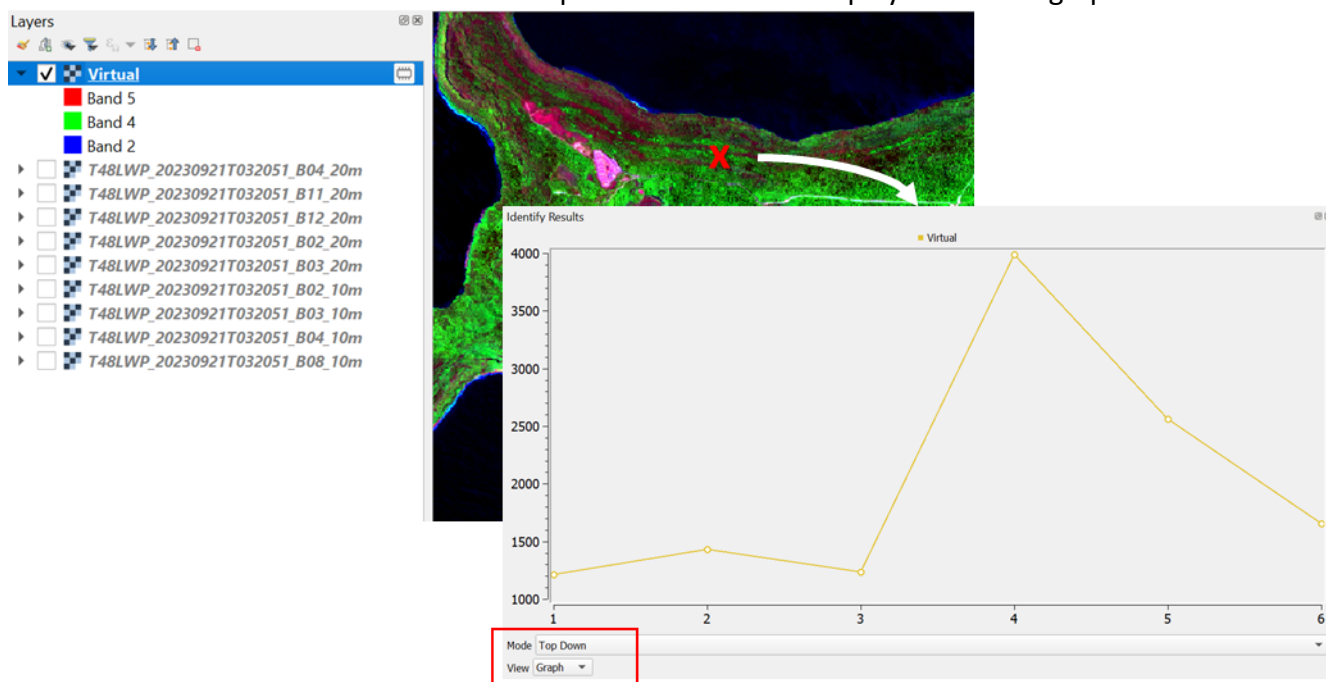
2.3 Spectra Mapping

When bands are stacked in the same file, it is also possible to interrogate individual pixel value locations to extract the DN values in each raster within the stack, and the associated 'spectral curve'.

1. Ensure the VRT layer is selected in the Layers panel (click on the layer, it will highlight in blue)
2. elect on the Identify tool (, and click on a pixel within the raster.
3. The results will be displayed in the 'Identify Results' window:



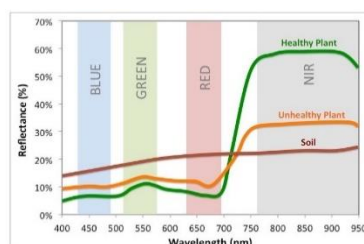
- To visualise these values as a graph, change the view from 'Tree' to 'Graph'
- The values from each band of the multi-band raster, intersected at the X,Y co-ordinate selected via the clicked location on the Map View will now be displayed in a line graph:



You can now visualise various spectra from different land covers, including grassland, forest, exposed soil / rock, artificial surfaces (tarmac, concrete etc.), water.

Note, this is only a 4-band raster product in the range of Visible to Near-Infrared. However, you can compare these spectra with spectral profiles acquired using the spectrometer.

Note that vegetated surfaces have a lower red value compared to the NIR value, whereas the reverse is true of exposed rock / earth locations.



NDVI difference calculation

In order to determine whether there have been disturbances to forest cover as a result of mining, multi-date imagery can be compared. To resolve the complexity of visual interpretation, or analysing multiple spectral bands simultaneously, a spectral index can be used to transform multiple values (bands) into a single value, such as the Normalised Difference Vegetation Index (NDVI).

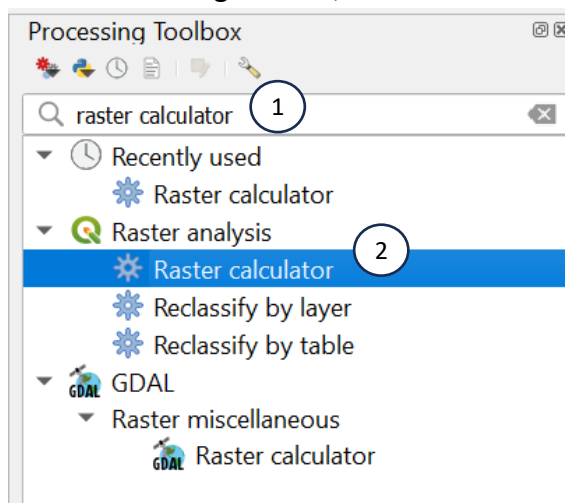
$$NDVI = (NIR - RED) / (NIR + RED)$$

For this exercise, a single index (NDVI) will be calculated for two dates (which emphasises the presence, or lack, of vegetation productivity), and then differenced to identify regions where productive, vegetated land, has been displaced by non-productive, non-vegetated surfaces. While not all 100% of these pixels with a negative transition will be deforestation from mining activities, this analysis will highlight areas of subsequent analysis and increase efficiency for detection.

It is recommended that you use the following dates: 06-11-2019 and 21-09-2023

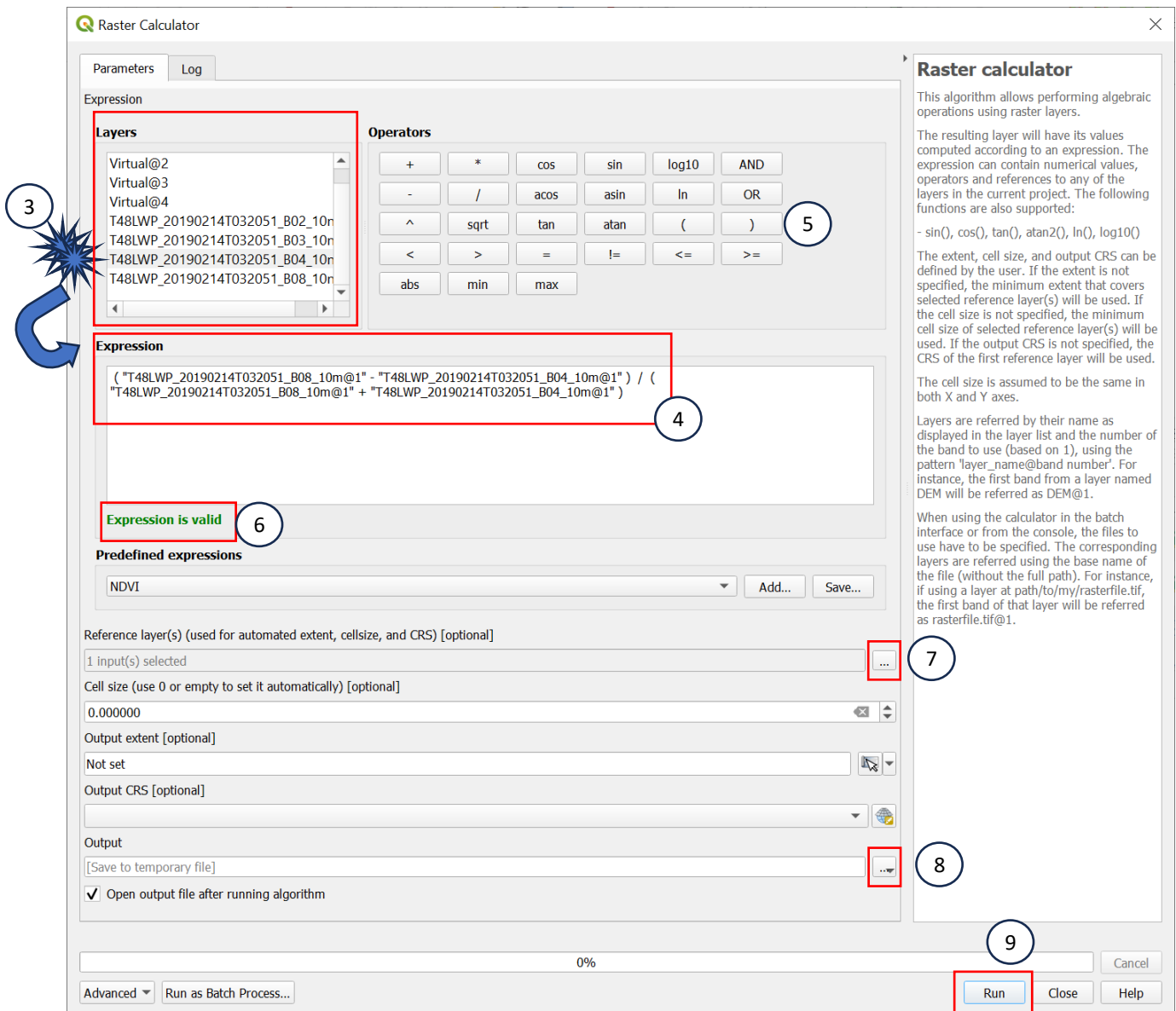
To calculate a single NDVI image:

1. In the Processing toolbox, search for the 'Raster Calculator'



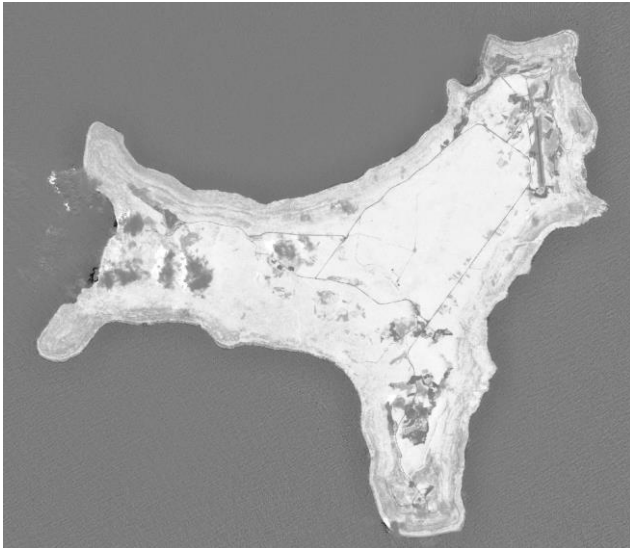
2. Select the 'QGIS Raster Analysis' Raster Calculator tool
3. By double-clicking on bands in the Raster Bands list, these are added into the 'Expression' box.
4. The aim is to input the NDVI equation using the bands that represent NIR (B08) and Red (B04)
5. Ensure brackets are used (these can be typed, or click the calculator icons)
6. Ensure the expression is correctly entered ((B8-B4)/(B8+B4)) – you will know it is valid (though perhaps not correct) if the message beneath the expression box is green and states it is a valid expression.

- Click on the three dot icon next to the 'Reference layer(s)' box, and click on the tick-box next to a layer that you are already using – this will ensure the raster grid has the same extent, pixel size, and co-ordinate reference system (CRS)
- Once the expression is correctly entered ($(B8-B4)/(B8+B4)$), specify the output filename and filepath using the box with the three dots to the right of 'Output layer' – again, use a sensible filename that details what the output filename will contain, e.g. include the image date and NDVI in the name.
- Select 'Run'

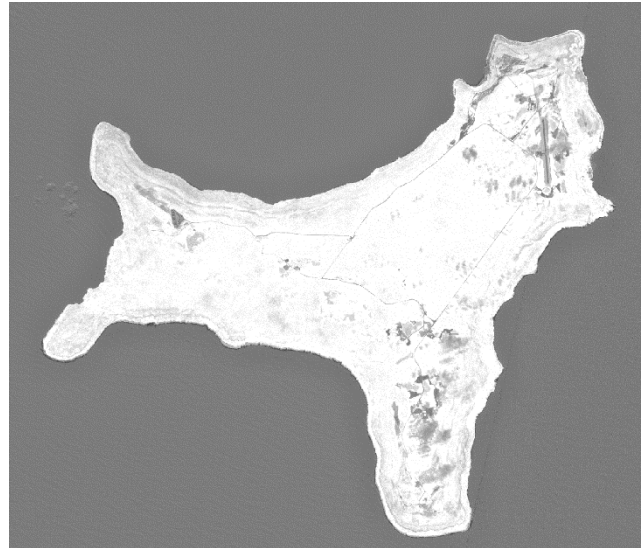


The output of this process will be a new raster image in your Layers list, which will be a single-band, greyscale image, containing the derived NDVI for each pixel for the chosen image date.

Repeat this process for the second image date.



06-11-2019



21-09-2023

Now that both dates have an NDVI image, these can be differenced, again using the raster calculator:

Raster Calculator

Parameters Log

Expression

Layers

T48LWP_20191106_NDVI@1
T48LWP_20230921_NDVI@1

Operators

+ * cos sin log10 AND
- / acos asin ln OR
^ sqrt tan atan ()
< > = != <= >=
abs min max

Expression

T48LWP_20230921_NDVI@1 - *T48LWP_20191106_NDVI@1*

Expression is valid

Predefined expressions

NDVI Add... Save...

Reference layer(s) (used for automated extent, cellsize, and CRS) [optional]

1 Input(s) selected

Cell size (use 0 or empty to set it automatically) [optional]

0.000000

Output extent [optional]

Not set

Output CRS [optional]

Not set

Output

[Save to temporary file]

☒ Open output file after running algorithm

0%

Advanced Run as Batch Process... Run Close Help

Raster calculator

This algorithm allows performing algebraic operations using raster layers.

The resulting layer will have its values computed according to an expression. The expression can contain numerical values, operators and references to any of the layers in the current project. The following functions are also supported:

- sin(), cos(), tan(), atan2(), ln(), log10()

The extent, cell size, and output CRS can be defined by the user. If the extent is not specified, the minimum extent that covers selected reference layer(s) will be used. If the cell size is not specified, the minimum cell size of selected reference layer(s) will be used. If the output CRS is not specified, the CRS of the first reference layer will be used.

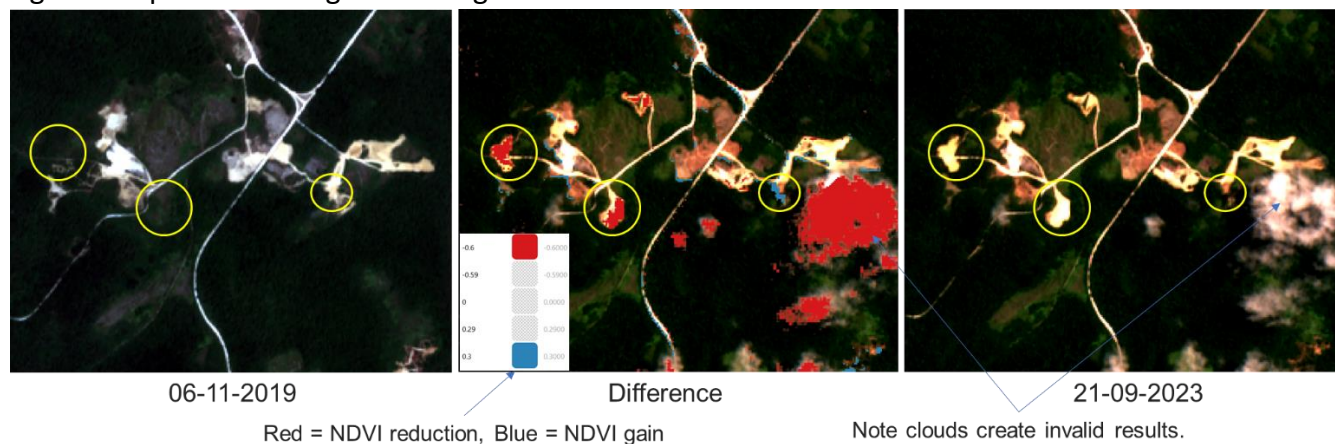
The cell size is assumed to be the same in both X and Y axes.

Layers are referred by their name as displayed in the layer list and the number of the band to use (based on 1), using the pattern 'layer_name@band number'. For instance, the first band from a layer named DEM will be referred as DEM@1.

When using the calculator in the batch interface or from the console, the files to use have to be specified. The corresponding layers are referred using the base name of the file (without the full path). For instance, if using a layer at path/to/my/rasterfile.tif, the first band of that layer will be referred as rasterfile.tif@1.

In the expression box, difference the post (after) date from the pre (before) date. The output of this process will be another new raster imager, with values representing the increases or decreases in NDVI between the two dates (negative values and positive values respectively).

Using the symbology, you can modify the visualisation of this greyscale raster to only show areas of significant positive or negative change.



To do this:

1. Right click on the derived NDVI difference raster in the Layers panel
2. Select the 'Properties' option, last in the list
3. Select the Symbology tab on the right, if not automatically selected
4. Change the 'Render type' to 'Singleband pseudocolour'
5. Modify the Min and Max value to '-0.5' and '0.5' respectively
6. Change the Mode to 'Equal interval'
7. Double-click the centre legend item and on the 'Select colour' pop-up window, change the 'Opacity' to 0
8. Click 'Ok'

