

GIS and Remote Sensing (ACNA6003)

Lecture 10: Sourcing Earth Observation data

Aim

In this session, students will gain experience of sourcing Earth Observation (EO) data from freely available datasets, specifically Landsat 8 (NASA) and Sentinel-2 (ESA), in order to conduct change detection analysis on Christmas Island, Australia, within QGIS.

1. Data sourcing

There are a number of online portals that provide freely accessible EO datasets. These online website allow users to search archives of data, view imagery, download data, and conduct basic analytics. In this session, students will practice using both Sentinel-Hub EO Browser and ESA's Copernicus Browser to source imagery from Sentinel-2 and Landsat 8.

NOTE: Users will need to create an account with both services. This is free.

Sentinel-Hub: <https://apps.sentinel-hub.com/eo-browser/>

Copernicus Browser: <https://browser.dataspace.copernicus.eu/>

NOTE: While both services provide much of the same service, as of 2024, Sentinel-Hub is being deprecated following the acquisition by Planet, and Copernicus Browser has only been functional for a year. Sentinel-Hub is more accessible and user-friendly, whereas Copernicus Browser has more features.

Sentinel-Hub

To search for imagery of Christmas Island from both Sentinel-2 and Landsat-8, on Sentinel-Hub, conduct the following steps (see Figure 1 below for screenshot):

1. Use the Search function (top right of the window) to search for 'Christmas Island', hit return, and then move the map window so that the island is centred on the screen (this is your image search extent).
2. Under the 'Discover tab on the right, toggle on 'Advanced search' for Sentinel-2 and set an appropriate cloud threshold (less than 20%)
3. Select (using the tick-box) 'Landsat 8-9' and set an appropriate cloud threshold (below 20%)
4. Set a date range by specifying the start and end dates.
5. Select 'Search'

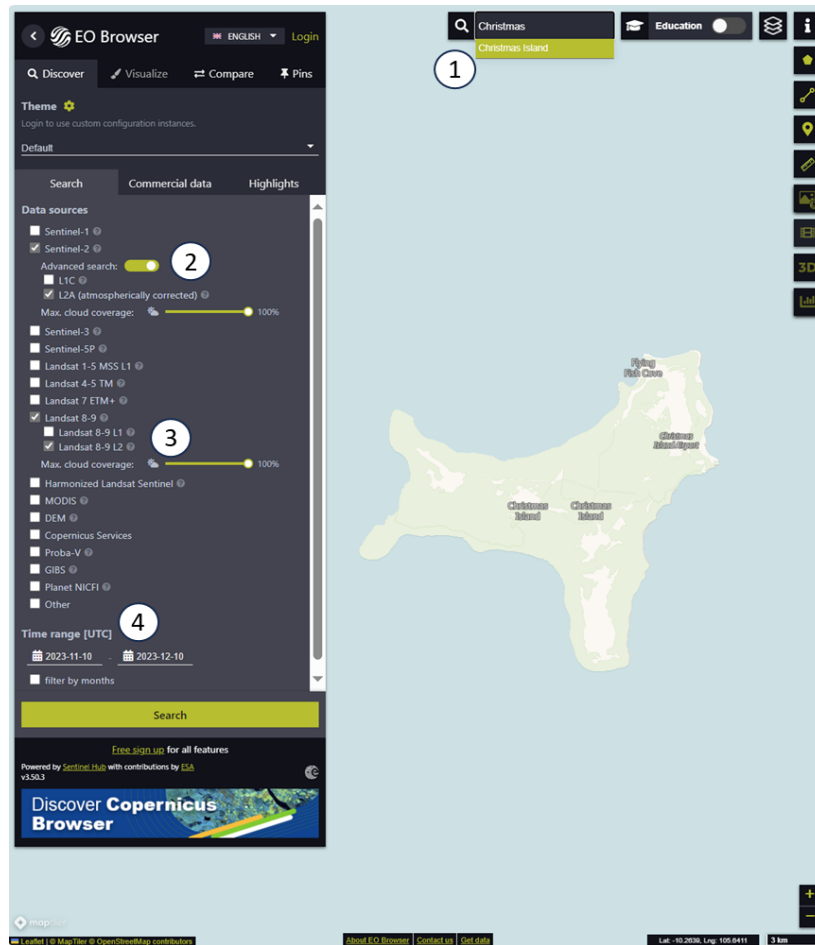


Figure 1: Screenshot of Sentinel-hub with 'Discover' tab options shown

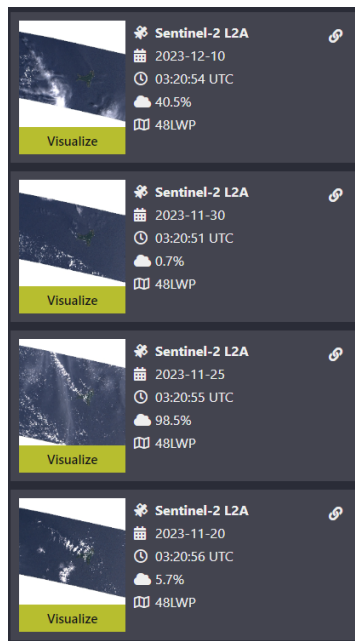


Figure 2: Example list of scenes identified from search

The result of this search will be a list of all scenes that meet the criteria provided (see Figure 2). The scenes have the following details:

- A small thumb-nail image (this only applies for Sentinel-2)
- Sensor name
- Date-time of image capture
- Cloud cover percent (across the scene)
- The tile (Sentinel-2 only)
- Sun angle (Landsat only)

NOTE: While data is continuously captured in swaths, data providers cut these into 'tiles' to standardise the extent

In order to see what a certain scene looks like, click the 'Visualise' button below a scene thumbnail in the list.

The 'Visualise' tab then opens (see Figure 3), allowing the user to select the way that the image is visualised spectrally, either in true colour (default Red Green Blue), false colour composite (e.g. SWIR), or derived spectral indices (e.g. NDWI).

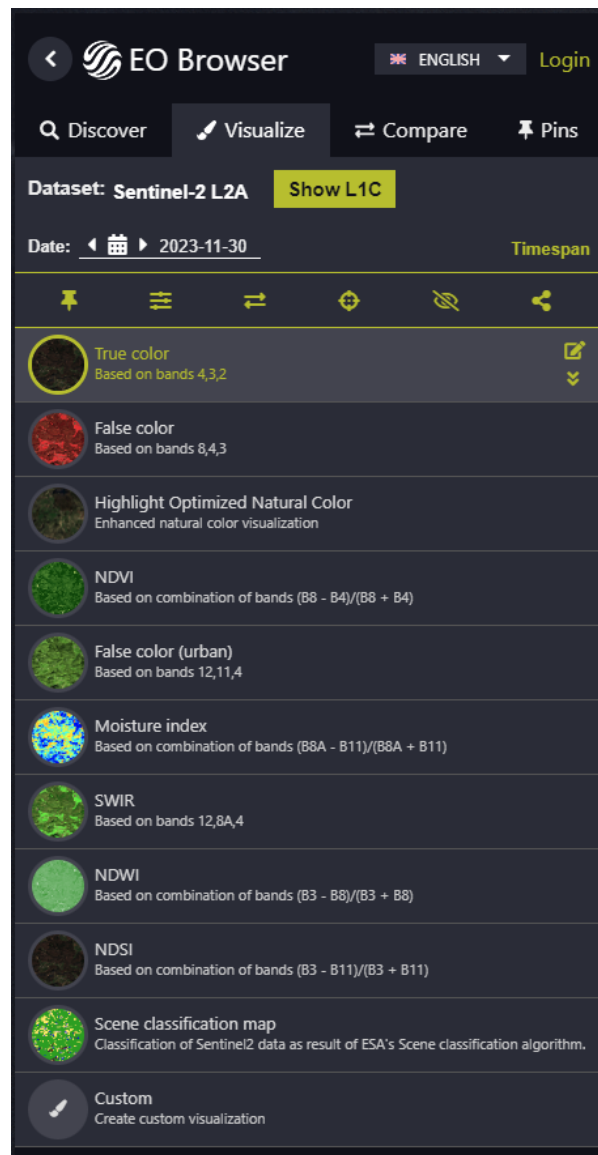


Figure 3: Visualise tab with band combinations and indices

In order to conduct change analysis, aim to source and identify dates of imagery that are:

- Low in cloud cover over the area of interest (the island)
- Close in season to reduce phenological differences (senescing and leaf-on / leaf-off)
- Close together in time period to capture discrete changes

For the Christmas Island change detection exercise, the following dates (in DD-MM-YYYY format) are most applicable:

Sentinel-2	Landsat-8
14-02-2019	29-03-2017
06-11-2019	29-10-2022
24-04-2021	
21-09-2023	
30-11-2023	

2. Data Download

Once suitable dates have been identified, the individual scene tiles can be downloaded for analysis on the user's local machine using GIS software.

Note: The following steps describe how to download scenes from both Sentinel-Hub and Copernicus Browser, but the scenes have been provided via Teams to save download time.

Sentinel-Hub

NOTE: Downloading scenes from Sentinel-Hub is restricted to 2500px by 2500px, so it is not possible to download a complete tile / scene for all of Christmas Island. The below documents how to download this subset area, but will not be used for analysis

First, users must ensure they are logged in to their Sentinel-Hub account via the 'Login' option located at the top left of the web page.

The viewing window acts as the extent definition i.e. the area shown in the viewing window is the image extent. The user must zoom to the area they wish to download before starting the download process.

To download the data for one scene, once the image has been visualised:

1. Select the 'Download image' icon on the right hand side of the screen – the download image dialogue box will open
2. On the Download image dialogue window, change to the 'Analytical' tab at the top.
3. Change the 'Image format' dropdown menu to 'TIFF (32 bit float)'
4. Change the 'Image resolution' dropdown menu to 'CUSTOM'
5. Specify the 'Resolution X' and 'Resolution Y' as 10 each
6. Change the 'Coordinate system' to the 'UTM' projection option
7. Under 'Layers' select all the 'Raw' heading by ticking the tick boxes

8. Click 'Download' – a compressed folder will automatically download

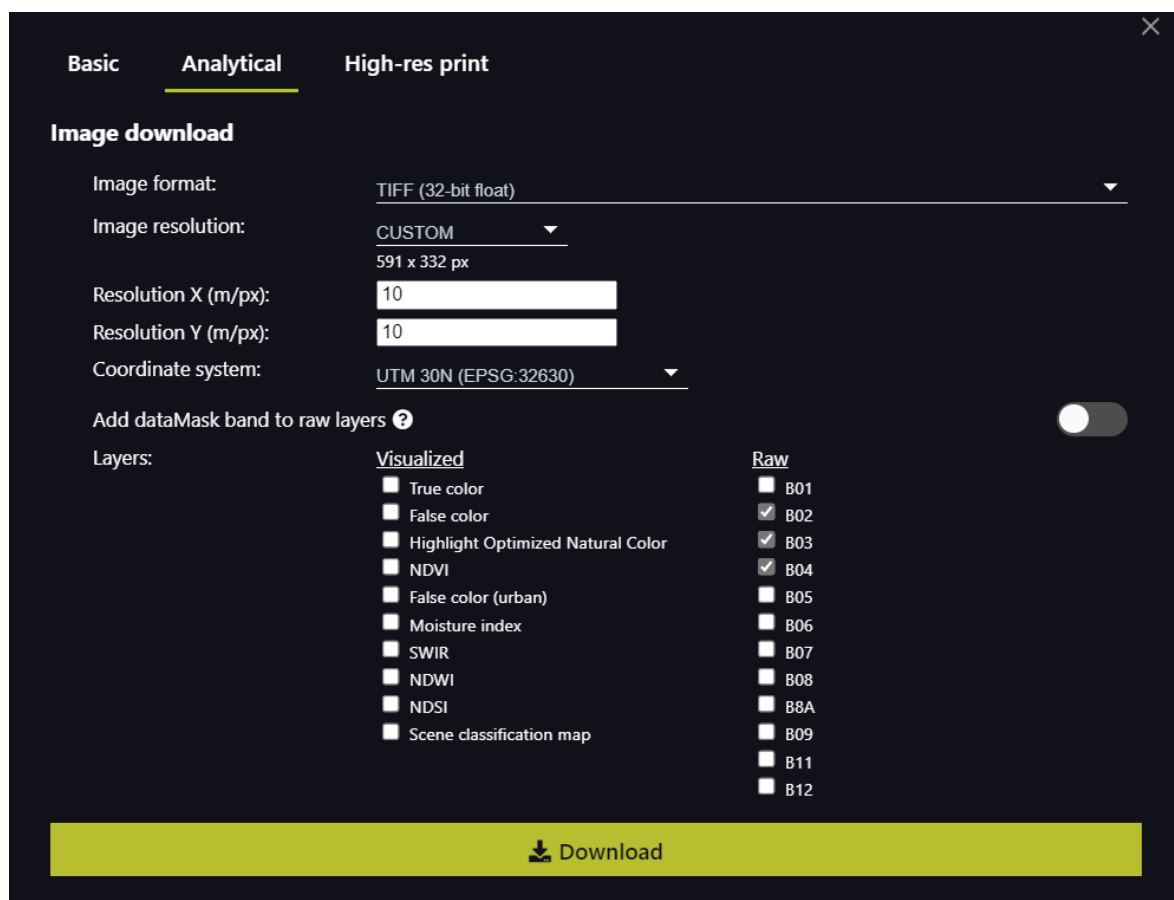


Figure 4: Analytical Image Download in Sentinel-Hub

NOTE: The downloaded imagery does not contain metadata and would be difficult to replicate if required due to the bespoke extent

Copernicus Browser

Unlike Sentinel-Hub, Copernicus Browser allows the user to download the raw tile data.

To download a tile, select the download icon next to the chosen scene (see Figure 5).



Figure 5: Copernicus Browser image download option (red square)

A compressed file beginning with 'S2' and ending in '.SAFE' will download. This is the raw file from ESA.

 S2A_MSIL2A_20230921T032051_N0509_R032_T48LWP_20230921T085659.SAFE

Download via Copernicus Browser is the optimum method for consistent, repeatable, quantified analysis, as the file format, image extent, pixel resolution are all the same with each image, which is not true of Sentinel-Hub. **Therefore, if the user is going to conduct multi-date analysis, be sure to use Copernicus Browser data!**

NOTE: There are different processing levels available via Copernicus Browser (see Figure 6):

- L1C
 - Top-Of-Atmosphere
 - TOA = **not** atmospherically corrected
 - This is for remote sensing experts with the knowledge and software to pre-process the 'raw' satellite data
- L2A
 - Bottom-Of-Atmosphere
 - BOA = atmospherically corrected, surface reflectance
 - Ready for analysis, but remember, assumptions have been made and associated error native within the file

The screenshot shows the Copernicus Browser interface. On the left, under 'DATA SOURCES', 'SENTINEL-2' is selected, and 'MSI' is checked. Below it, 'L1C' and 'L2A' are listed. A red arrow points from the 'MSI' checkbox to a list of search results on the right. The results show four entries, each with a thumbnail, a file name, mission details, instrument, size, and sensing time. The first two entries are for 'S2A_MSIL1C_20230921T032051_N0509_R032_T48LWP_20230921T083017.SAFE' and the next two are for 'S2A_MSIL2A_20230921T032051_N0509_R032_T48LWP_20230921T065059.SAFE'. The first entry is labeled 'S2MS1C' and the second is labeled 'S2MS2A'. A red arrow points from the 'S2MS1C' label to the 'S2MS2A' label, indicating that the same image (date) can have both processing levels available.

Note that the same image (date) can have both processing levels available

Figure 6: Processing levels of Sentinel-2 data available via Copernicus Browser

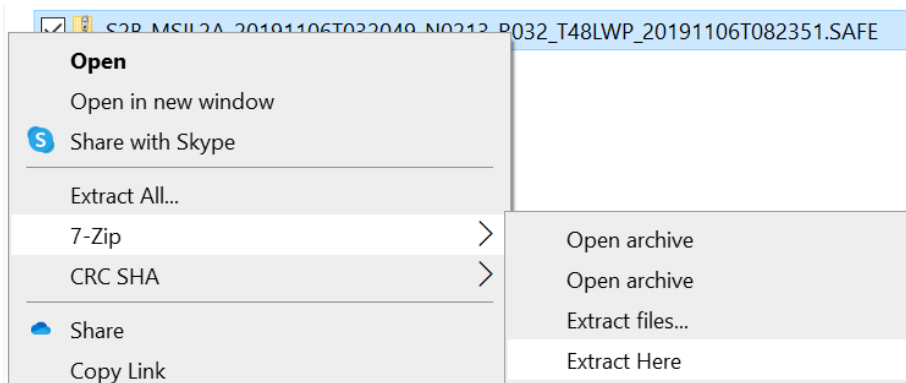
3. Extraction

In order to open and utilise the downloaded, compressed, .SAFE files (from Copernicus Browser), these first need to be extracted.

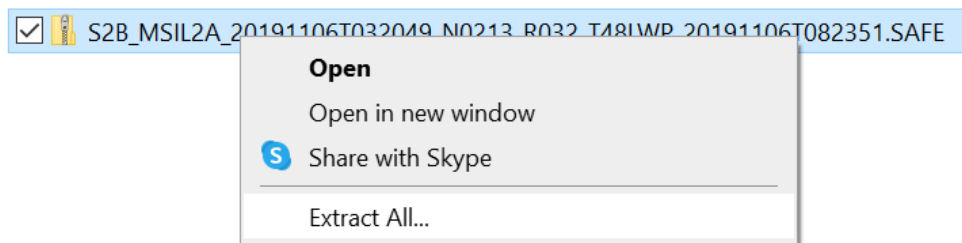
To extract the data:

1. First, ensure the compressed .SAFE file is stored in an appropriate location within the user's file system
2. Either:

- a. If 7-Zip is installed, right click on the filename and select '7-Zip > Extract Here', or,



- b. Right click on the file name, select 'Extract All...' and agree the file path.



A folder with the same name will be created, and all the contents uncompressed into this folder.

The folder and file format of the raw data provided by ESA contains lots of sub-folders and long filenames, which provide information about the date of sensor, capture date and time, and processing details.

For example:

S2A_MSIL2A_20190214T032051_N0211_R032_T48LWP_20190214T074549.SAFE

S2A = Satellite ID (Can be Sentinel-2 A or B depending on which sister satellite was capturing the image)

MSI = Sensor: Multi-Spectral Instrument

L2A = Processing level: Either L1C (Level 1 – Unprocessed) or (Level 2 – Atmospherically corrected)

20190214 = Date of image capture (YYYYMMDD format)

T032051 = Time of image capture (HHMMSS format)

T48LWP = Tile ID: The continuous swath data is divided up into a global grid to aid storage / naming / sourcing.

20190214T074549 = Date and Time of processing

4. Visualisation

Having downloaded and extracted the raster image data ready for analysis, it can now be visualised within GIS software, QGIS.

Copernicus Browser

When using the raw .SAFE data downloaded from Copernicus Browser, the image data is stored under the following pathway:

[Filepath]\[Filename].SAFE\GRANULE\L2A_XXXXXX_XXXXXX_YYYYMMDDTHHMMSS\IMG_DATA

The image data folder, “IMG_DATA”, contains three separate folders for each of the separate pixel resolutions (10m, 20m, and 60m respectively, see Figure 7 below):

- R10m
- R20m
- R60m

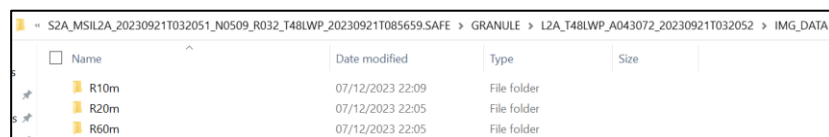


Figure 7: Resolution folders

NOTE: some spectral band rasters are present in multiple resolutions, for example bands B02, B03, and B04, are present in the 10m resolution folder (R10m) and the subsequent folders, R20m and R60m, where it is resampled in each.

Each image file ends in jp2, with the following spectral band file names:

Sentinel-2 bands	Filename format	Spatial resolution (m)
Band 1 – Coastal aerosol	XXXXXX_YYYYMMDDTHHMMSS_B01_60m	60
Band 2 – Blue	XXXXXX_YYYYMMDDTHHMMSS_B02_10m	10
Band 3 – Green	XXXXXX_YYYYMMDDTHHMMSS_B03_10m	10
Band 4 – Red	XXXXXX_YYYYMMDDTHHMMSS_B04_10m	10
Band 5 – Vegetation red edge	XXXXXX_YYYYMMDDTHHMMSS_B05_20m	20
Band 6 – Vegetation red edge	XXXXXX_YYYYMMDDTHHMMSS_B06_20m	20
Band 7 – Vegetation red edge	XXXXXX_YYYYMMDDTHHMMSS_B07_20m	20
Band 8 – NIR	XXXXXX_YYYYMMDDTHHMMSS_B08_10m	10
Band 8A – Narrow NIR	XXXXXX_YYYYMMDDTHHMMSS_B8A_20m	20
Band 9 – Water vapour	XXXXXX_YYYYMMDDTHHMMSS_B09_60m	60
Band 10 – SWIR – Cirrus	XXXXXX_YYYYMMDDTHHMMSS_B10_60m	60
Band 11 – SWIR	XXXXXX_YYYYMMDDTHHMMSS_B11_20m	20
Band 12 – SWIR	XXXXXX_YYYYMMDDTHHMMSS_B12_20m	20

Table 1: Sentinel 2 spectral bands, filename formats, and pixel (spatial) resolutions (m)

To visualise any image file, load it into QGIS using the methods previously documented:

1. Directly click and drag the file from the File Explorer window into the QGIS Map View
2. Use the 'Layer' dropdown option, selecting 'Layer' > 'Add Layer' > 'Add Raster Layer...'

Bring in a single layer, and note that the layer is in greyscale. Each pixel is represented by a single value, and the range of grey, from black to white, represents the lowest to highest pixel values in the image (see Figure 8 below).

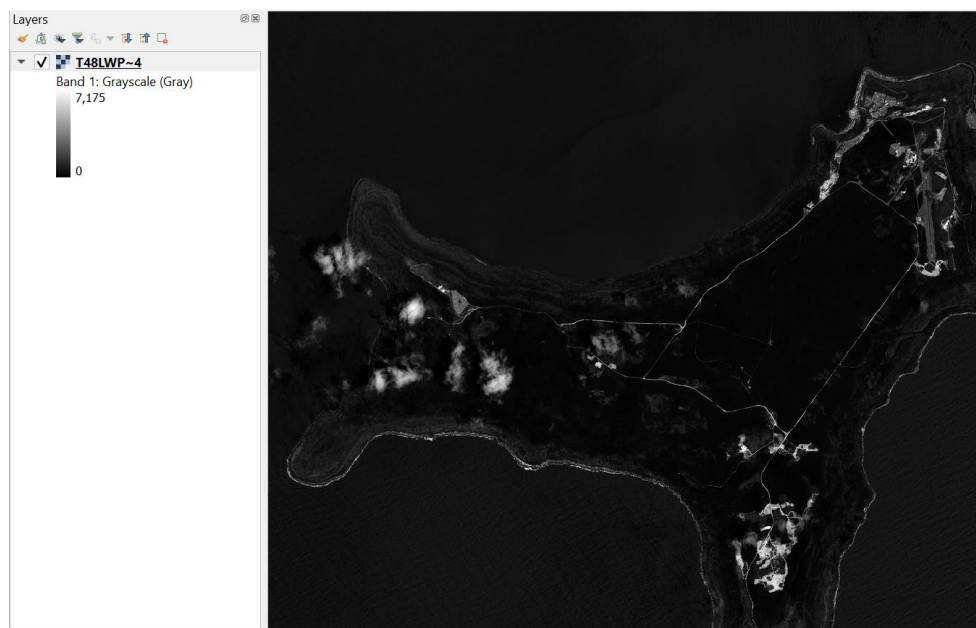


Figure 8: Example of a grayscale image loaded in QGIS

To load a true-colour composite (Red, Green, Blue) the user must first load Bands 2, 3, and 4 (B02, B03, and B04 respectively) into QGIS. These will each load separately as individual layers within QGIS and be represented in greyscale (Figure 9).

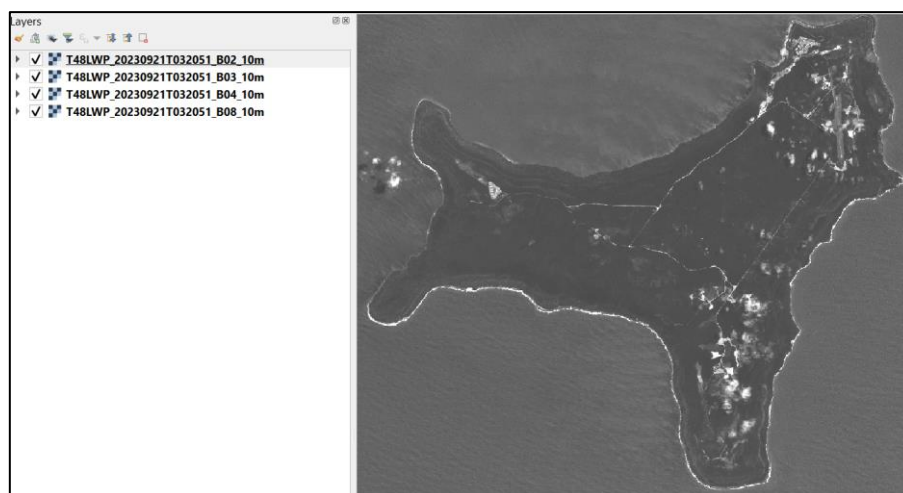


Figure 9: Individual Sentinel-2 image bands loaded in greyscale

In order to visualise the data as a single image file in RGB format, a new stacked image file will need to be created, called a Virtual Raster (VRT) file. Specifically, a VRT file does not duplicate data, instead it is a text file which captures the filepaths of multiple images that are then presented as a single stacked multi-band raster.

To create a VRT, select the 'Build Virtual Raster' option from the 'Raster' dropdown (see Figure 10):

'Raster' > 'Miscellaneous' > 'Build Virtual Raster'

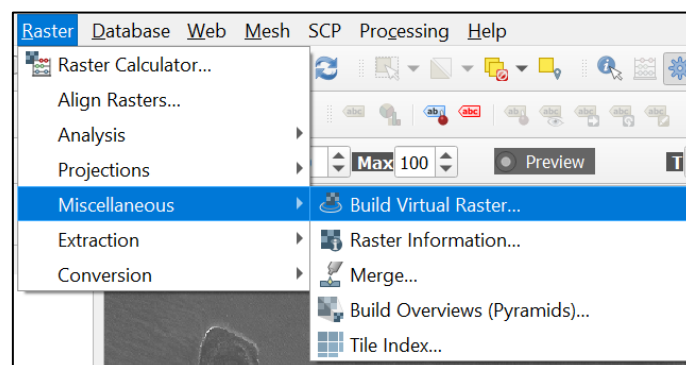
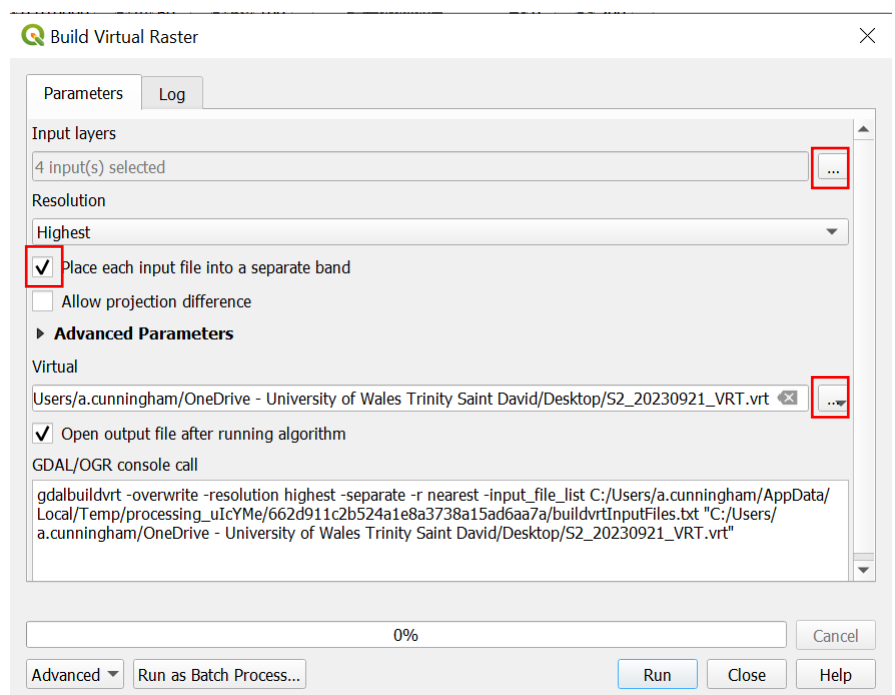


Figure 10: Build Virtual Raster tool

With the tool window open:

1. Click the 3 dots button next to the 'Input Layers' box, which loads the 'Input Layers' window
2. Specify the files to include in the virtual raster – in this instance all 10m image layers from a single scene
3. Click 'OK'
4. Change the Resolution dropdown option to 'Highest'
5. Select the 'Place each input file in a separate band' checkbox
6. Click the 3 dots button next to the 'Virtual' box and specify where to save the output file –



be sure to provide an appropriate name, for example, the name of the image acquisition date

7. Click 'Run' - The saved VRT file will automatically load into QGIS.

The virtual raster (VRT) will hold the input bands in alphabetical order, for example, if all four 10m pixel resolution bands ('R10m') were used, the stack order would have been as follows:

- Band 1 (top): B02, Blue
- Band 2: B03, Green
- Band 3: B04, Red
- Band 4 (bottom): B08, Near-Infrared (NIR)

Therefore, the RGB display will select the first three bands and display these respectively across the Red, Green, and Blue (RGB) channels, thereby meaning the following bands are displayed:

R: B02, Blue; G: B03, Green B: B04, Red

As a result, this is actually a false colour composite, as the red and green spectral bands are not displayed in the corresponding colour on the screen. To achieve true-colour visualisation, the user must adjust the image symbology properties and change which spectral bands are displayed in the Red and Blue channels.

To edit the image symbology properties, right click on the VRT layer name, then select 'Properties'. With the 'Symbology' tab selected on the left side, click on the drop down option for 'Red band' and change it from 'Band 1' to 'Band 3', and likewise, on the 'Blue band' drop down option, change from 'Band 3' to 'Band 1':

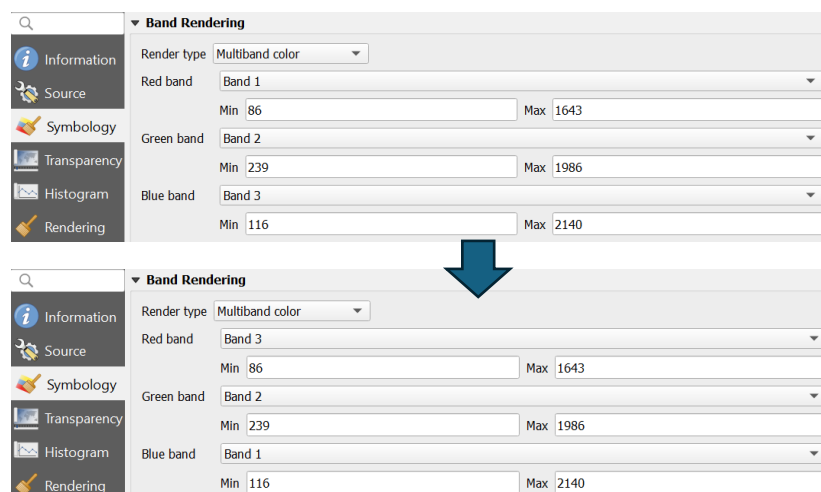


Figure 11: Editing RGB raster display band order

Once the user has clicked 'OK', a true-colour display of the scene should be displayed.

In order to display false-colour composites, trial changing the selected bands in the RGB display order. For example, to show a Near-Infrared false colour composite, which displays Near-Infrared spectral values in the red display channel, change the order as follows:

R: Band 4: B08, Near-Infrared

G: Band 3: B04, Red

B: Band 2: B03, Green



Due to the vegetation cell structure typically having higher variation in range and magnitude of spectral responses in near-infrared (NIR), healthy vegetation with display in a range of red colour.

Note: If wishing to display other spectral bands, for example, Shortwave Infrared (SWIR) bands, which are natively at 20m pixel resolution, the process of generating the VRT would have to be repeated, with 20m pixel resolution image bands first imported / loaded from the 'R20m' folder. All visible (B02, B03, B04), near-infrared (NIR), and short-wave infrared (SWIR) bands (B11 and B12) can be loaded from the R20m folder, and included in the VRT input selection.

5. Spectral signature plotting

With a multi-band raster in QGIS, and containing spectral bands, the user can now begin to explore the spectral values and spectral 'curves' present within overlapping pixels. As VRT's contain rasters of the same extent and pixel resolution, the pixels in stacked bands align and overlap. This allows the user, by selecting a specific co-ordinate, to identify the values within each stacked, aligned band (see Figure 12)

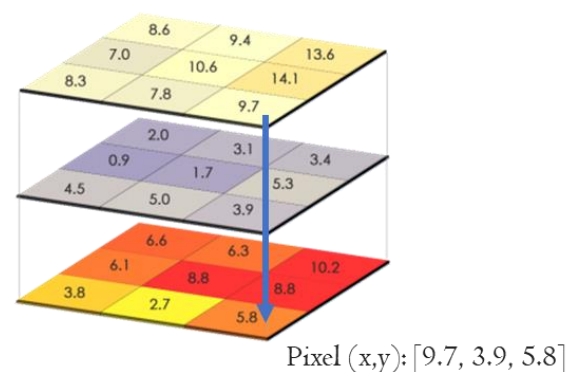


Figure 12: Illustrated example of extracting pixel values from stacked bands at a specific co-ordinate (x,y)

This array of values can then be plotted in an X,Y chart. This allows the user to see the spectral 'behaviour' across the different wavelengths, and compare these plotted pixels to other spectral signatures / curves, for example, theoretical or generalised spectral patterns of common land cover features (Figure 13).

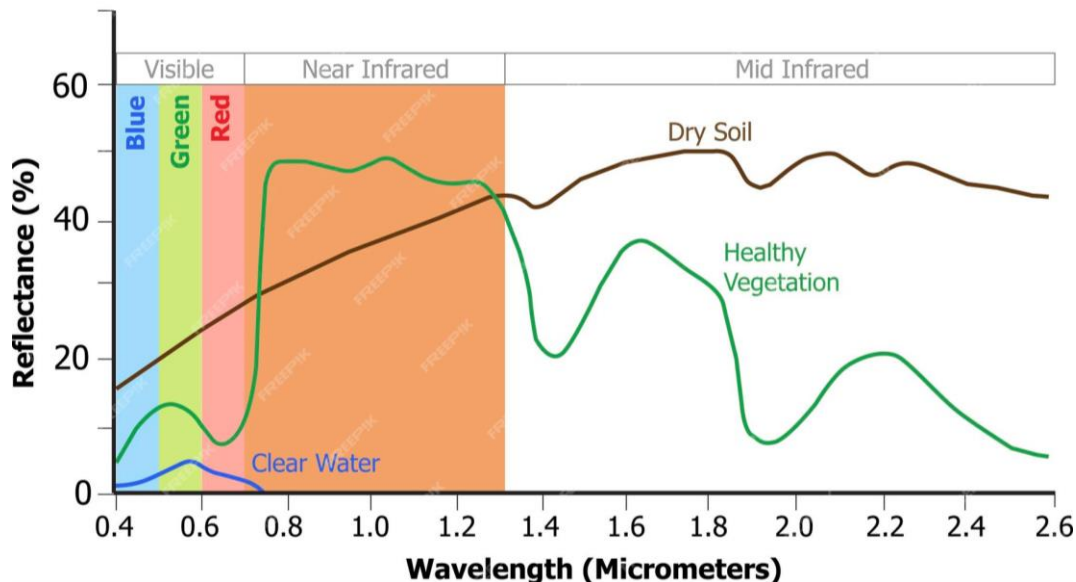


Figure 13: Example spectral signature patterns for three land cover features.

In order to display the spectral values for a pixel within an image stack (VRT), the user can use the 'Identify' tool as in previous practicals.

1. Locate the 'Identify' tool in the top toolbar – it is a blue circle with the letter 'i' and



2. Click on this icon to select the 'Identify' mode – note, the user's cursor will not change to a black cursor with the letter 'i' above it.
3. Ensure the layer the user wants to interrogate is selected, by clicking on it's name in the layer's panel list so it is selected (highlighted)
4. Then, click anywhere within the image – thereby selecting the pixel where the cursor intersects.
5. If it is not already open, the 'Identify' panel should emerge (typically right side of the Map View).
6. Change the properties to 'Mode – Current Layer' and 'View – Graph' using the drop down menu at the bottom of the panel (see Figure 14)

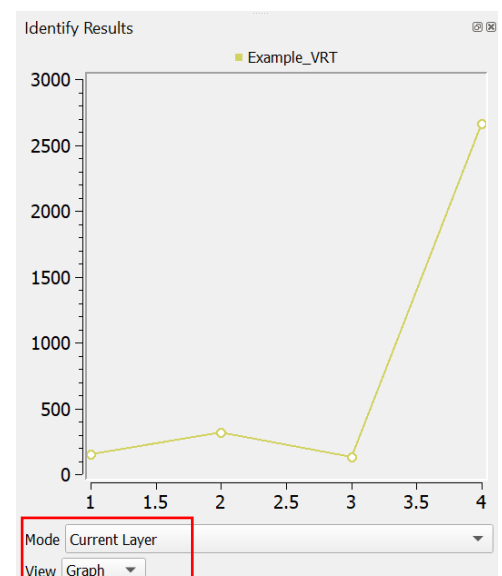


Figure 14: Example 'Identify' graph with properties highlighted in red box outline

7. The pixel values for the intersected co-ordinates of the click on the map view will now be displayed in a graph, in sequential order, e.g. the first band in the stack will be at point 1 on the X-axis, the second band will be at point 2 on the X-axis, etc. NOTE: The symbology display order does not influence the graphing order, so even if a false-colour composite is shown (e.g. R:B08, G:B04, B:B03), the graph will still display ALL bands in sequential order, 1, 2, 3, 4 etc.
8. Explore the spectral curves of different pixels by clicking on different areas of the image in the Map View – note the graph redraws on each click, so previous clicks cannot be viewed simultaneously.

The user can now explore the spectral behaviour of different land cover surfaces to understand how each wavelength interacts in terms of reflectance. It may be worth making a note of the band order in the VRT image stack, and the different parts of the spectrum these represent e.g. Band 1 in the stack = Blue etc.

6. Index calculation

While stacked images allow for visualisation in RGB colour, and associated human interpretation of the visual imagery, this is not a quantifiable process.

In addition to this, the separation of pixels that contain changes is subjective when done visually, which would lead to inconsistent results if repeated or conducted by multiple individuals. Using a quantifiable pixel value allows for analysis to be conducted which is repeatable and would produce consistent results.

As imagery contains multiple spectral bands, with a lot of redundancy (for example, all healthy vegetation has low red and blue values comparative to green values, regardless of species and location), exploring patterns across multiple spectral bands simultaneously is complex and computationally arduous. Instead, spectral indices can be used when transform the relationships between spectral bands into a single value.

For this case study, the Normalised Difference Vegetation Index (NDVI, Rouse et al. 1973) will be used, as it explores the relationship between the Red spectral band and Near-Infrared (NIR) spectral band (see Figure 15), making it sensitive to vegetation condition. As healthy vegetation typically has high chlorophyll absorption (and therefore low red spectral reflectance), and high reflectance of NIR spectral energy as a result of healthy plant cells, there is a strong ratio between the two reflectance values. Conversely, unhealthy, stressed vegetation has a low ratio between the two caused by the reduction in NIR and increase in red reflectance (see Figure 16).

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

Figure 15: Normalised Difference Vegetation Index (NDVI) calculation (Rouse et al., 1973)

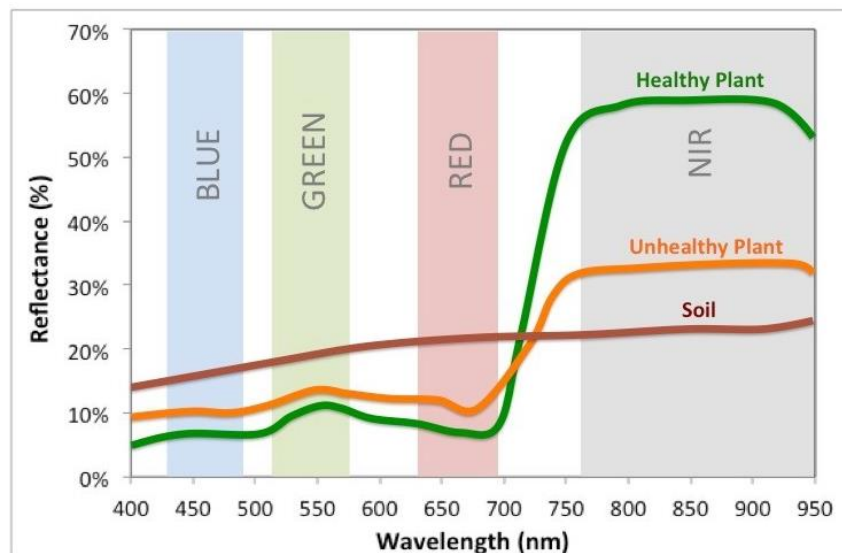


Figure 16: Visualisation of spectral behaviour of vegetation under varying conditions

In this case study, it is expected that pixels containing healthy forested areas would have higher NDVI values than pixels with disturbed areas impacted by mining and tree displacement.

In order to calculate the NDVI pixel values, a raster calculator is used, which applies the arithmetic formula to the values in each pixel. The individual spectral bands being used must be loaded into QGIS first.

1. Load the spectral bands into the QGIS software if they are not already present:
 - a. For a single image date (in this case study example, this could be the Sentinel-2 image of Christmas Island taken on 24/04/2021)
 - b. Specifically bands 4 (red) and 8 (NIR) need to be loaded – the rest are not needed
2. Open the 'Raster Calculator' tool by either:
 - a. Clicking on the 'Raster' toolbar at the top, and selecting the first option from the drop-down menu, 'Raster Calculator'
 - b. Searching in the Processing Toolbox for 'raster calc' and selecting the 'Raster Calculator' tool under the QGIS 'Raster analysis' options.

Once the 'Raster Calculator' window is open (Figure 17):

3. Note that the raster layers that are open in QGIS are presented in the 'Raster Bands' window on the left
4. Enter a formula into the 'Raster Calculator Expression' at the bottom of the window, by typing directly, or clicking the required raster layers and 'Operators' button icons are required, for example, to calculate the NDVI for the expression shown in Figure 17), the user would:
 - a. Open brackets by either typing '(' or clicking on the open bracket operator icon would add this to the Expression window
 - b. Double click on the NIR band for the selected scene from the 'Raster Bands' list, in this example, "T48LWP_20230921T032051_B08_10m@1", or type this exactly as spelt in the Raster Bands list.
 - c. Add a 'minus' symbol, by either typing "-" or clicking on the subtract Operators icon.
 - d. Double click on the red band for the selected scene from the 'Raster Bands' list, in this example, "T48LWP_20230921T032051_B04_10m@1", or type this exactly as spelt in the Raster Bands list.
 - e. Close brackets by either typing ')' or clicking on the close bracket operator icon would add this to the Expression window
 - f. Add a division by either typing '/' or clicking on the division operator icon
 - g. For the second half of the equation, repeat steps a - e, but replace the minus symbol in command c with a addition / plus symbol.
 - h. The formula once finished should look the same as shown in Figure 17.
5. Specify the output file name and location by clicking on the 3 dot icon next to the 'Output layer' option.
 - a. Ensure to choose a sensible file name, that contains perhaps the image date, and the name 'NDVI', and store in a suitable location on the computer
6. To ensure the spatial extent (pixel size, raster extent etc.) are the same as the input, click on the 'Use Selected Layer Extent' button under the Spatial Extent options.
7. Click 'OK' to run. If the expression was entered correctly, the process should run and add the output raster to the QGIS project. NOTE: an error in the expression can still produce a result, but not the desired outcome, due to the arithmetic expression not being the desired one. For example, switching the addition and subtraction elements would still produce a raster, but the values would differ from a raster calculation where the mix-up had not taken place. Therefore, remember to always check the expression carefully as a result output raster does not always guarantee the expected outcome.

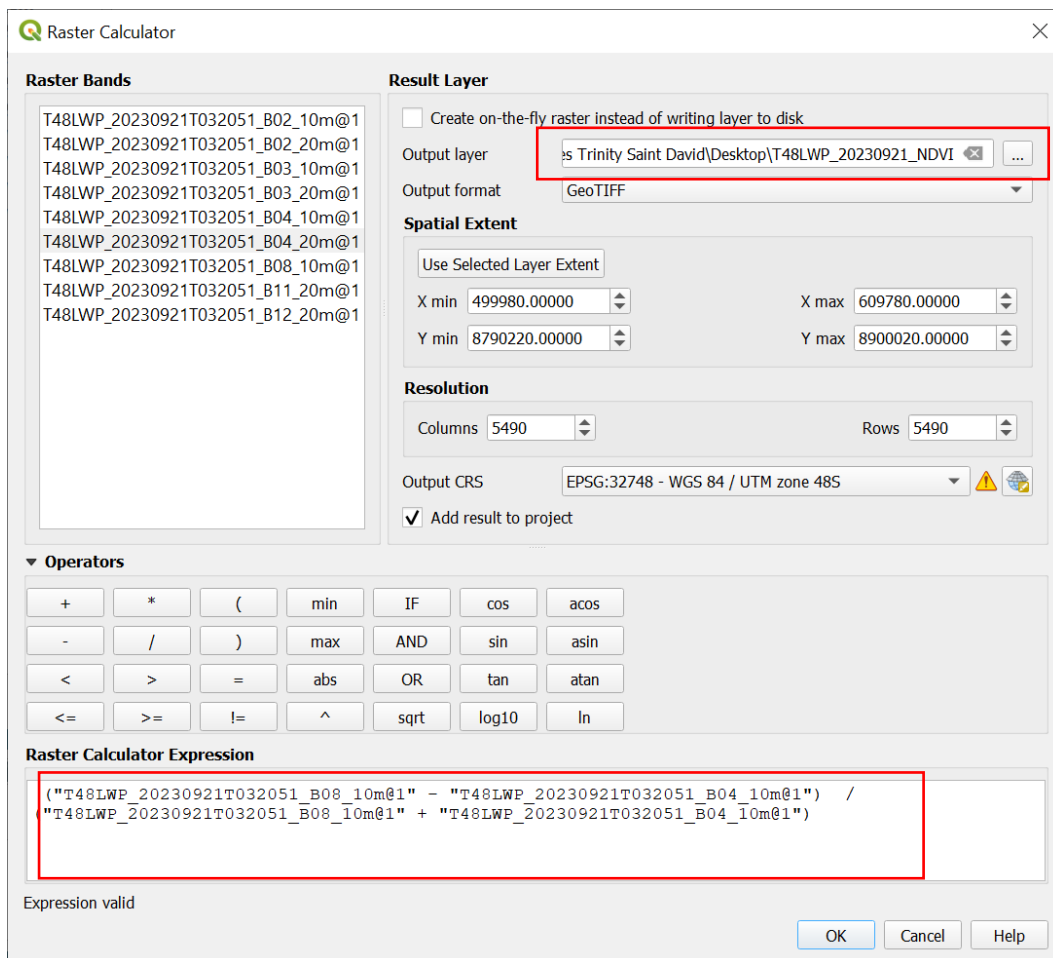


Figure 17: Calculation of NDVI using the 'Raster Calculator' tool

The output is a new single raster band image file, now located in the 'Layers' tab on the left of the screen. The layer can be visualised, and is composed of greyscale values that will range from between -1 and 1, where high values (above 0.5) are associated with highly productive healthy vegetation, low positive values (below 0.5) are associated with poor condition / unhealthy vegetation, or exposed earth, and negative values are associated with water.

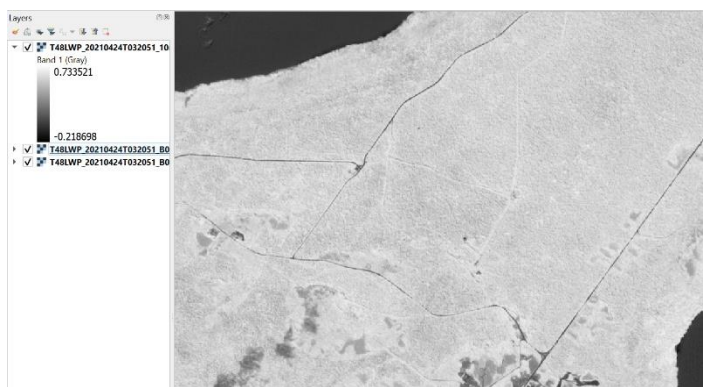


Figure 18: Example NDVI output image and greyscale raster symbology

Explore the pixel values in the new layer using the ‘Identify’ tool, and then repeat the NDVI calculation for another image date, so there are two NDVI image outputs.

7. Image differencing

When more than one NDVI image is generated, these can then be arithmetically analysed in the same manner used to analysis two raster bands from the same image. Ultimately each NDVI image represents the NDVI relationship at the time of image capture for each scene, and therefore, the user now has a single comparable attribute for two or more points in time which can now be compared using raster arithmetic, also known as ‘raster algebra’ (see Figure 19).

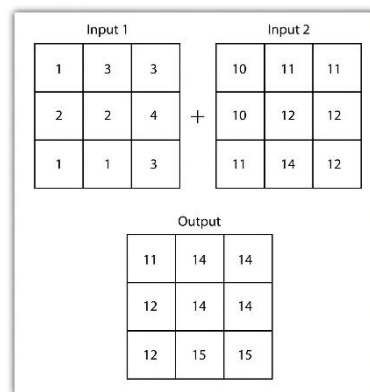
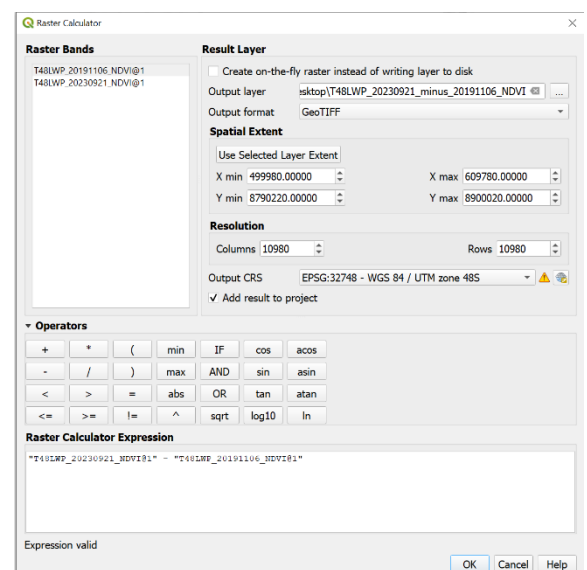


Figure 19: Representation of raster algebra, specifically addition of two input rasters

By subtracting one date NDVI from another, the user can see the temporal relationship between the two dates for this one metric for every pixel. By subtracting the post (after) date from the prior (before) date, the output would contain positive values where the NDVI had increased, and negative values where the NDVI had decreased between these two points in time.

To difference the two NDVI images:

1. Open the ‘Raster Calculator’ tool as above
2. Using either direct entry via typing in the ‘Raster Calculator Expression’ box, or clicking on the Raster Bands and Operators icons, enter the equation to subtract the ‘Before’ date from the ‘After’ date e.g. ‘T48LWP_20230921_NDVI’ – T48LWP_20191106_NDVI’
3. Specify a suitable filename and save location under the ‘Raster Result’ options



4. Ensure the pixel / raster extent matches by clicking on the 'Use Selected Layer Extent' button under the Spatial Extent options.
5. Click 'Ok' to run

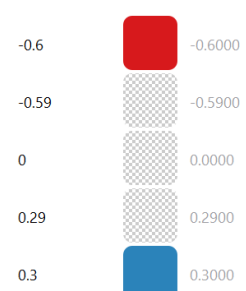
The output will be a new single band raster image, that will appear in the 'Layers' tab. Again, this layer will be greyscale, but the pixels will represent the trajectory in NDVI between the two dates. Use the 'Identify' Tool () to explore the pixel values in the NDVI difference output raster and compare these values to the input NDVI values.

8. Symbolology

As the output is a greyscale single band raster, it will contain only shades of grey. If the user wishes to emphasis areas of significant loss or gain in NDVI in this output, and ignore areas of little to no change, then the visualisation of this raster layer can be modified.

1. Right click on the output layer
2. Select the last option from the menu, 'Properties' and the 'Layer Properties' window will appear (Figure 20)
3. Under the Properties window, ensure that the 'Symbolology' tab / option is highlighted on the left side.
4. Change the 'Render type' under 'Band Rendering' section to 'Singleband Psuedocolor'
5. Click on the coloured 'ramp' and select a colour ramp styling of preference, ideally one with 3 bands of colour, creating a contrast from 'low', to 'mid', to 'high'
6. To reduce the impact of nominal / minimal change areas, where no significant changes have taken place, the middle color band of the ramp can be changed to transparent by:
 - a. Double clicking on the coloured square for that class / range to bring up the 'Select color' window (Figure 21)
 - b. Changing the Opacity to 0%
 - c. Click 'OK'
7. Click 'OK' on the Layer Properties window

Having completed this, the pixels in the raster layer will show colours attributed to this new symbology definition, and any with pixel values in that central band of values will be transparent.



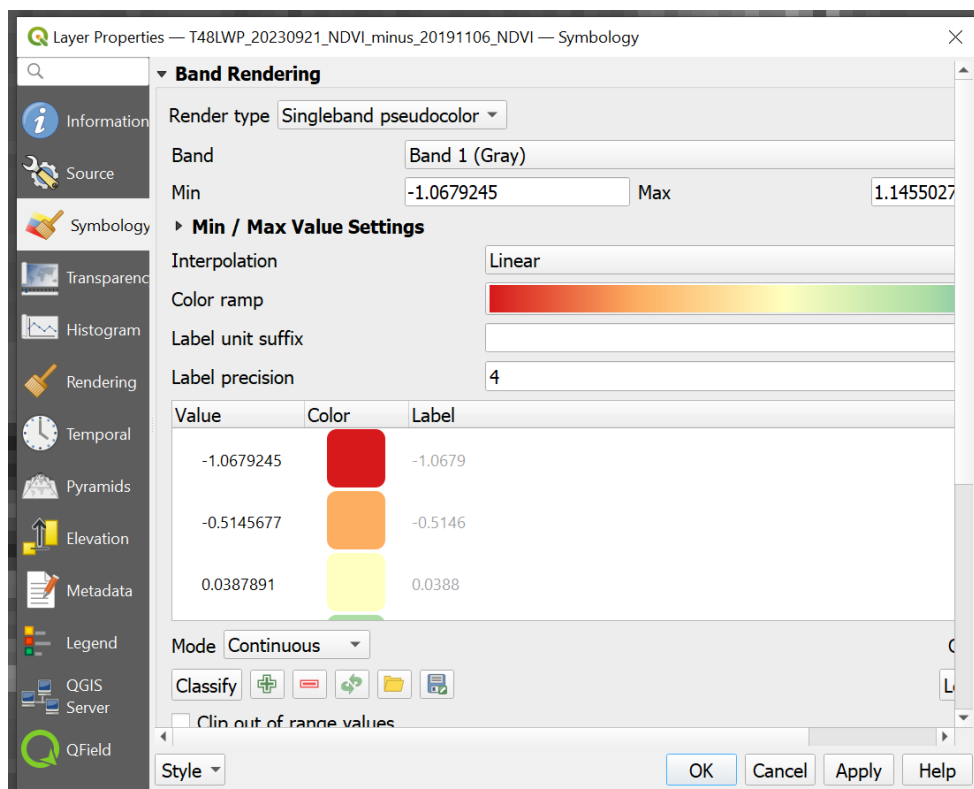


Figure 20: Example 'Symbology' window

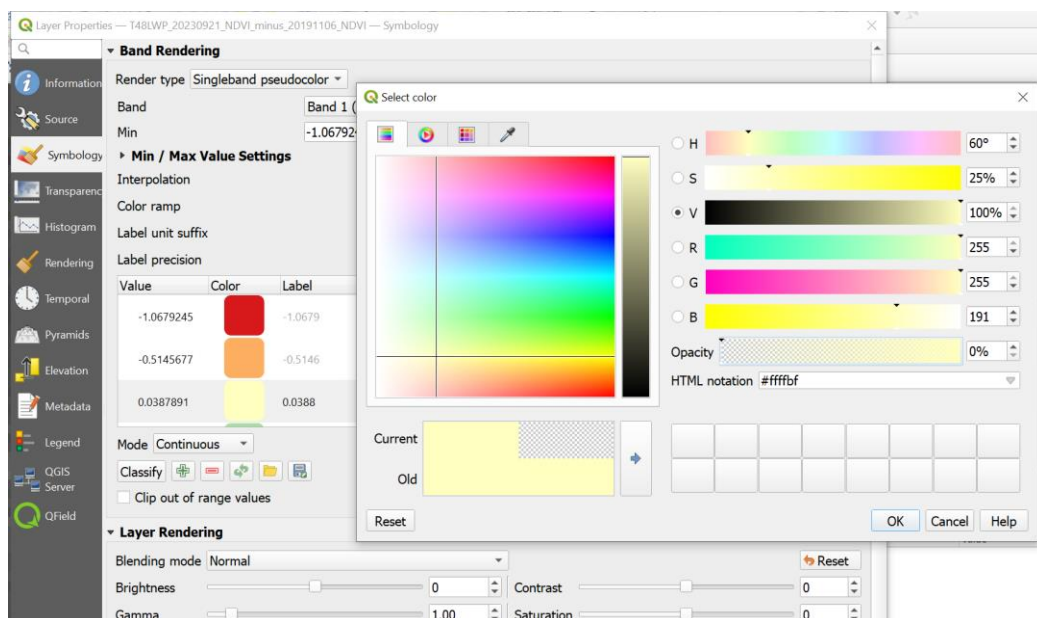


Figure 21: Example colour selection

The user can now visualise areas of high magnitude change in both the positive and negative direction with NDVI between the two example dates, whereby positive values

represent increase in vegetation state / presence, whereas negative values represent areas of vegetation loss.

NOTE: Clouds unfortunately hinder this process, as their presence is captured in pixels, and therefore, because clouds have a low NDVI value, appear as 'changes' where clouds have been present / absent between the two consecutive images.

The User can now explore visually the output to identify regions of forest habitat loss on Christmas Island caused by the active mining and associated clearance for mining roads and the mining activity itself.

