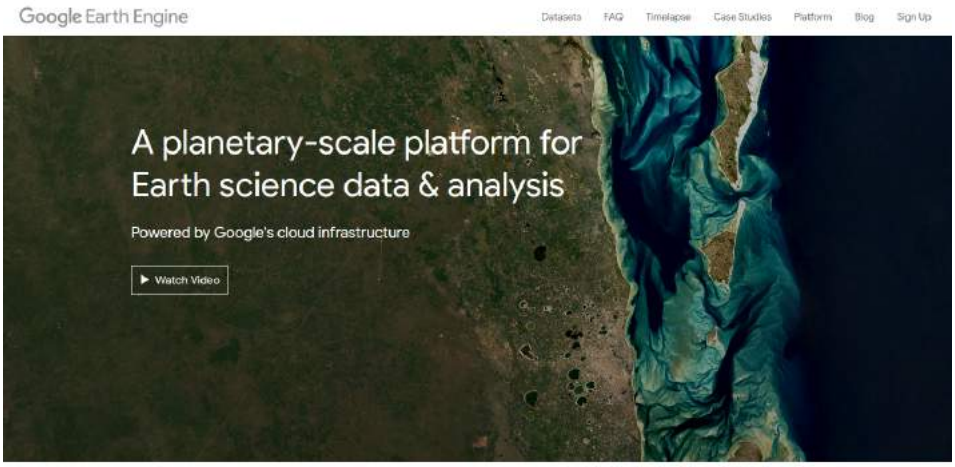
GIS TUTORIAL 4: Introduction to Google Earth Engine

In this tutorial you will receive a brief introduction to Google Earth Engine and learn how to edit and run simple scripts to produce Sentinel-2 and Landsat-5 satellite imagery.

1 Getting Started

1.1 Google Earth Engine introduction

Google Earth Engine (GEE) should run from any modern browser – you do not need to install extra software. Chrome is a good choice as it is also created by Google.



Meet Earth Engine

Google Earth Engine combines a multi-petabyte catalog of satellite imagery and geospatial datasets with planetary-scale analysis capabilities and makes it available for scientists, researchers, and developers to detect changes, map trends, and quantify differences on the Earth's surface.

To use GEE, you need to sign in with your Google account here:

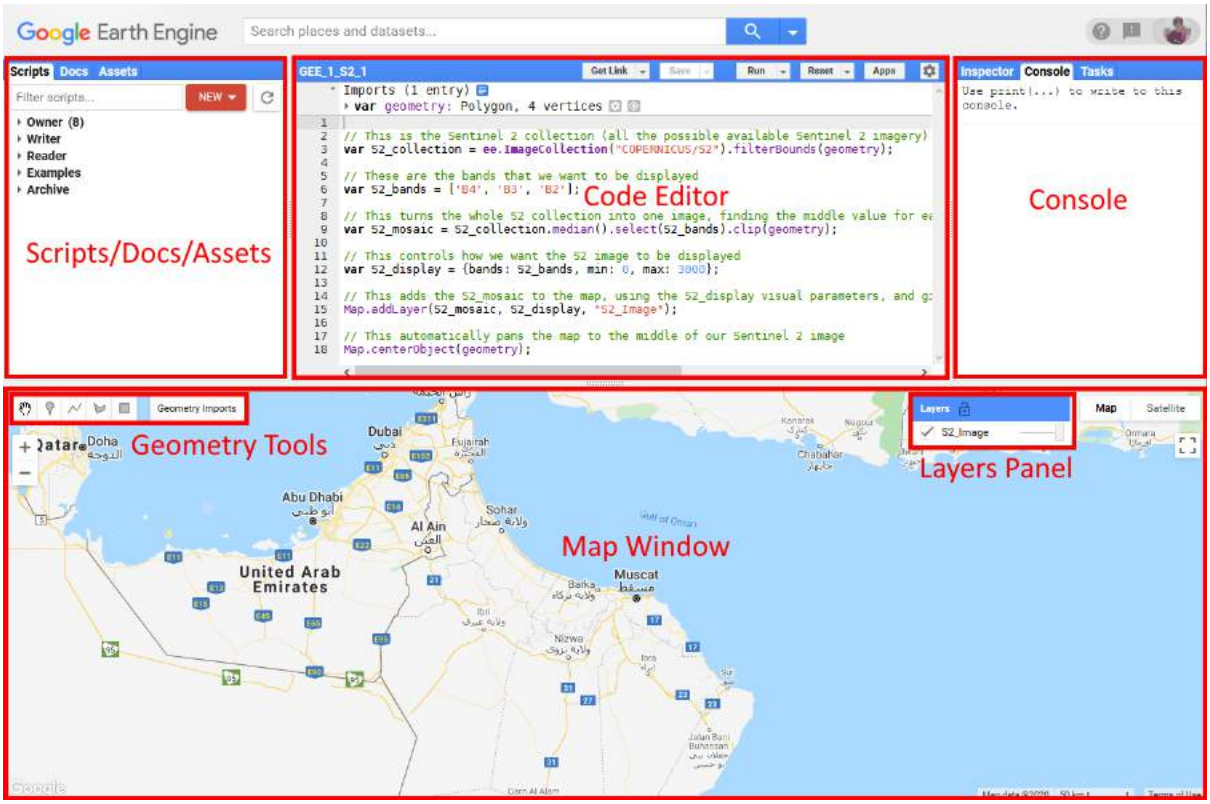
https://code.earthengine.google.com/.

If you have not already signed up you will need to do so here:
https://earthengine.google.com/signup/.

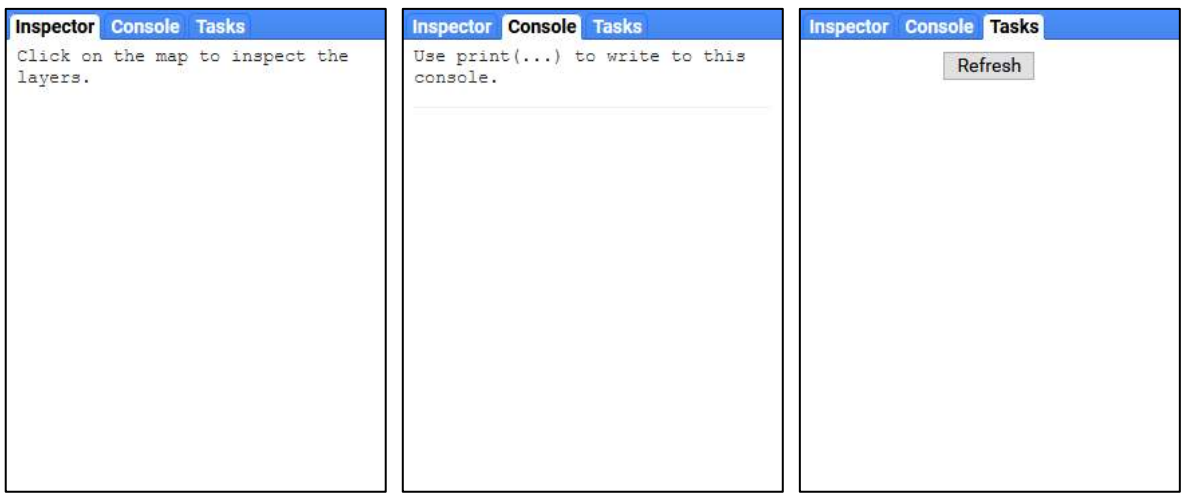
- It will take a few days for Google to approve your access to GEE, so please do this promptly if you have not already done so. Once you have signed in you will see the following screen when you visit the main website.

1.2 Google Earth Engine interface

Unlike QGIS which is controlled through a graphical user interface, GEE relies on scripts – programming code that gives the platform its instructions. The interface is made up of the following windows and controls which will be referred to repeatedly throughout these tutorials.



The Console window has two other tabs, the Inspector and Tasks tabs which need to be clicked on to be accessed. The same is true for the Scripts/Docs/Assets window, but we won't be using these as much.



2 Editing and Running A Simple Sentinel-2 Script (video tutorial playlist)

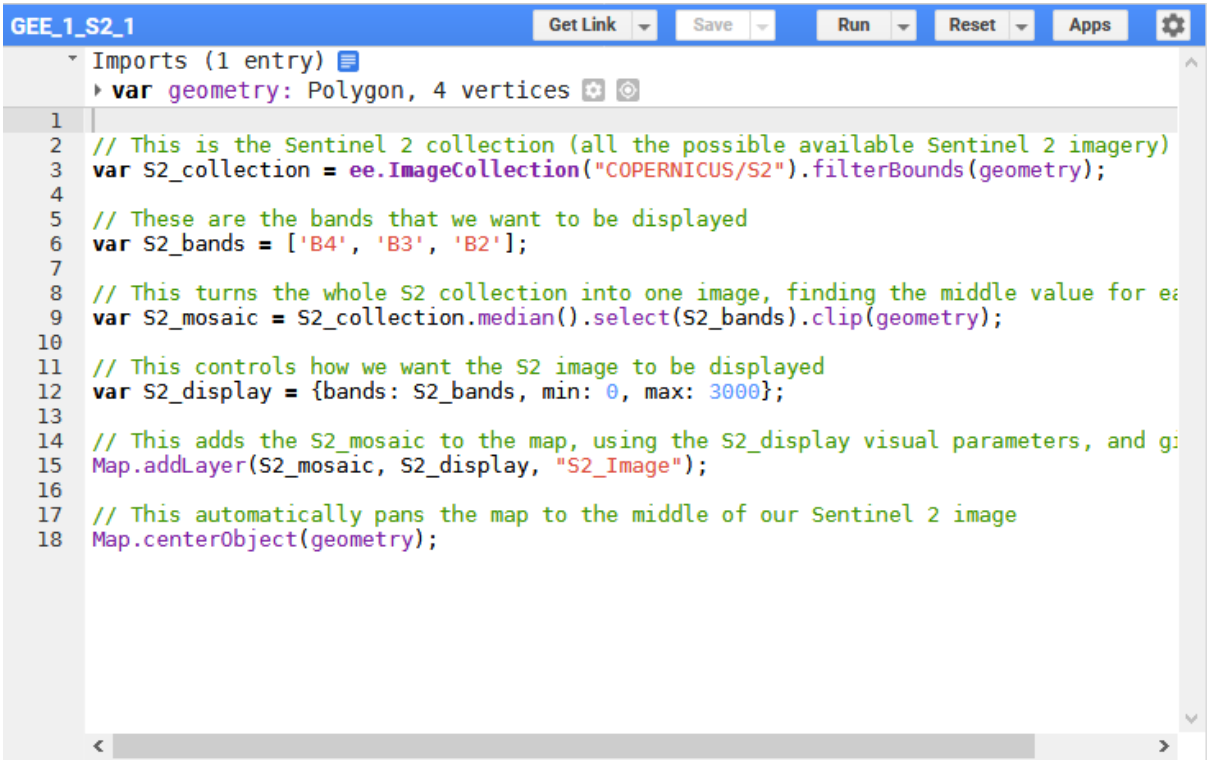
We are going to be using a simple script to view and download some Sentinel-2 imagery.

- Sentinel-2 is a satellite owned and operated by the European Space Agency that has been collecting data since June 2015.
- Unlike a lot of satellite imagery, Sentinel-2 is free to download and use.
- It has a ten-metre resolution and thirteen different bands. It is very similar to Landsat which we have used before, but the ESA version instead of NASA. You can find out about the satellite here.

The script has already been written for us. What we are going to do in the next steps is access it, edit it to our own specifications, and then run it.

- Click here to open the simplest version of the script in your web browser https://code.earthengine.google.com/e02fefa580c9e7d1a0af6e96f5baccf5

First, have a look at the text in the Code Editor.



It may look complicated, but basically each line is an instruction to tell the script to do something:

- The green text is notes to explain what each part of the script does:
  - Line 3: imports the Sentinel-2 collection
  - Line 6: defines the Sentinel-2 bands we are interested in
  - Line 9: creates a single image by taking the middle value of all the available Sentinel-2 imagery for each pixel
  - Line 12: tells GEE how to display our image
  - Line 15: tells GEE to display it
  - Line 18: automatically moves the Map View to the centre of the red rectangle.

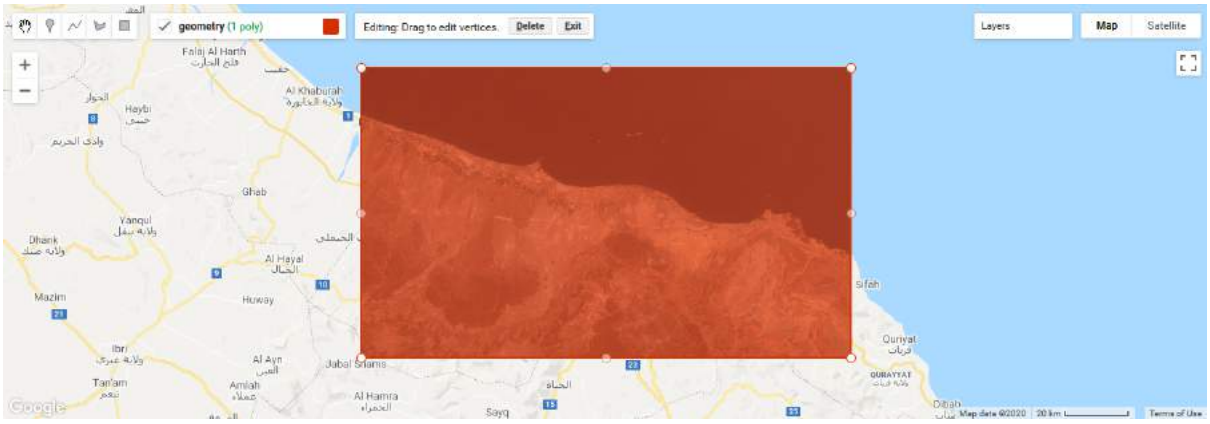
As we work through the tutorial, we will encounter longer versions of the scripts which have more instructions to refine our results further.

2.1 Geometry tools and defining your area of interest (video tutorial)

When we first open each version of the script, the map will automatically zoom to an area of Oman and some Sentinel-2 imagery for that area will start to load.

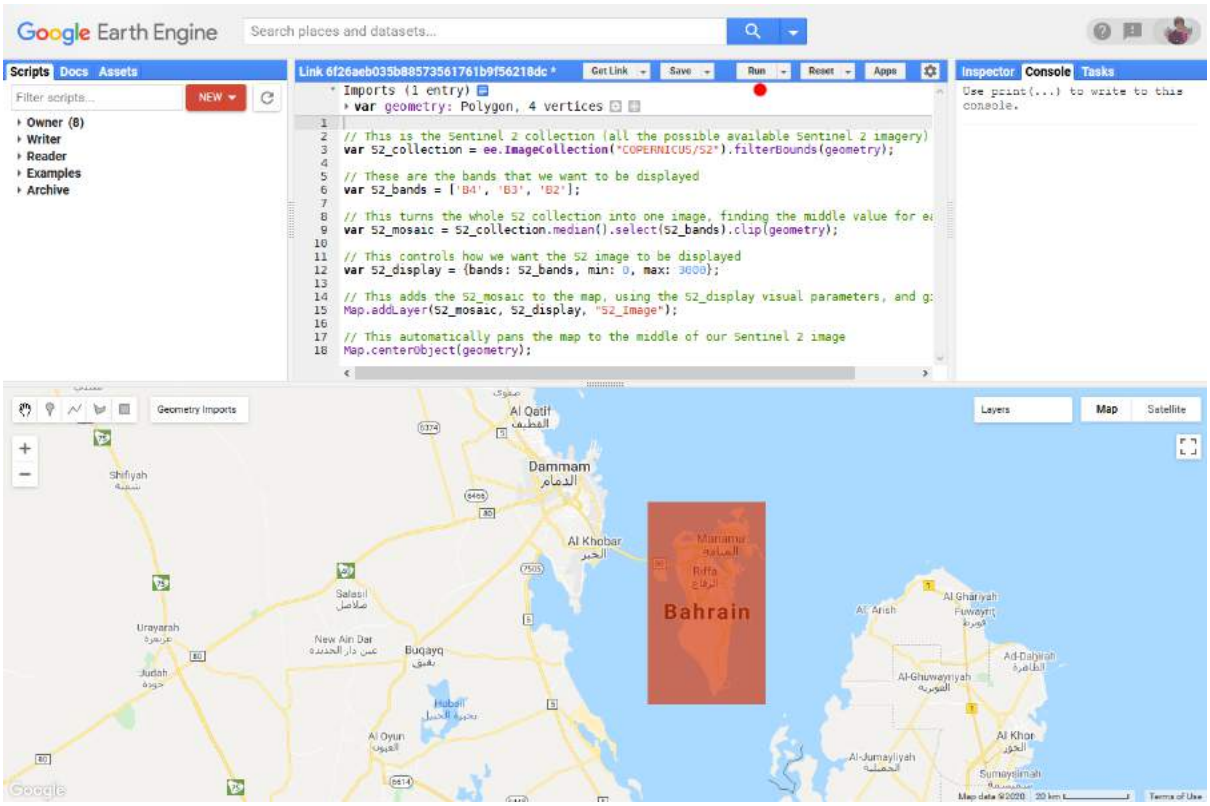
- So, the first thing we will do is change this to our own area of interest.
- Click "Geometry imports" in the Geometry Tools and turn on the "geometry" polygon.

- Click on the polygon and click Delete.



- Navigate in the map to your own area of interest and use the Rectangle tool to define a new area.
- Once you have drawn your rectangle press the Stop Drawing (Hand) button.

- Now click Run in the Code Editor.



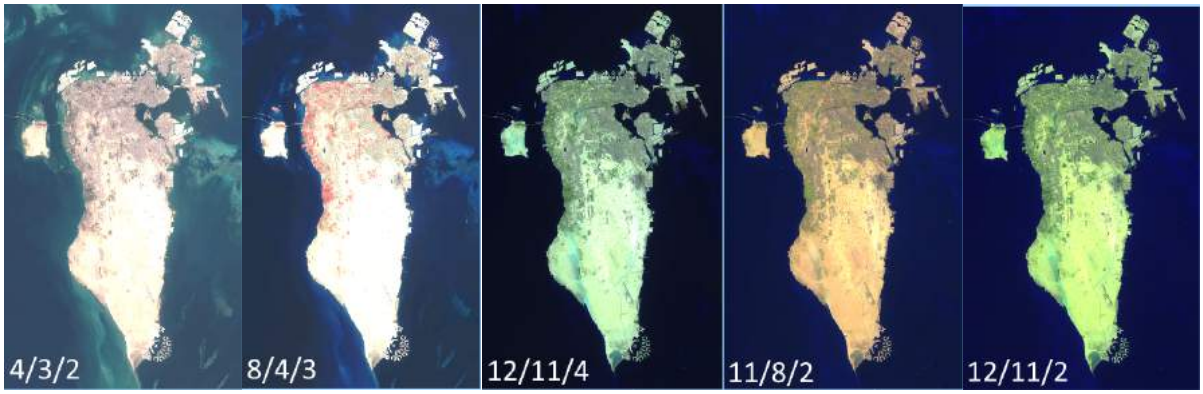
- Turn off the red rectangle in the Geometry Imports menu and wait for the imagery to load

- You can now zoom in and explore the Sentinel-2 imagery of your area.

2.2 Editing the Sentinel-2 bands in the Code Editor (video tutorial)

By default, the script is programmed to create a "true colour composite" – an image with colours that we would recognise with the naked eye.

We are now going to change the Sentinel-2 bands to make different colour composites which highlight certain features in the satellite imagery, such as geology, urban areas or vegetation. This is very useful when we are assessing change to landscape over time and examining disturbances and threats to archaeological sites.



- Click here to open the next version of the script https://code.earthengine.google.com/42eee8ffa6ee2e80e400cdd2c9b58028
  - This will return us to our default example in Oman.
- Find the "BANDS" section of the script in the Code Editor.
- Change the red "B" numbers in "S2_bands" to match one of the band combinations listed in the notes and click Run.

```
Imports (1 entry)
  var geometry: Polygon, 4 vertices
1
2  // This is the Sentinel 2 collection (all the possible available Sentinel 2 imagery)
3  var S2_collection = ee.ImageCollection("COPERNICUS/S2").filterBounds(geometry);
4
5  // BANDS: these are the bands that we want to be displayed
6  // **** We can change these bands to create different Sentinel-2 colour composites
7  // **** **** 4/3/2 - natural colour composite - most similar to colours that we see with the naked eye
8  // **** **** 4/3/1 - bathymetry composite - excellent for showing up the depth of water bodies
9  // **** **** 8/4/3 - colour infrared compsite - vegetation shows up clearly as bright red
10 // **** **** 12/11/4 - urban area compsite - excellent for showing up urban areas in purple
11 // **** **** 11/8/2 - agriculture composite - excellent for tracking the health of crops
12 // **** **** 12/11/2 - geology composite - excellent for showing up differences in geology
13
14 var S2_bands = ['B4', 'B3', 'B2'];
15
16 // This turns the whole S2 collection into one image, finding the middle value for each pixel
17 var S2_mosaic = S2_collection.median().select(S2_bands).clip(geometry);
18
19 // This controls how we want the S2 image to be displayed
20 var S2_display = {bands: S2_bands, min: 0, max: 5000};
21
22 // This adds the S2_mosaic to the map, using the S2_display visual parameters, and giving it the name "S2_Image"
23 Map.addLayer(S2_mosaic, S2_display, "S2_Image");
24
25 // This automatically pans the map to the middle of our Sentinel 2 image
26 Map.centerObject(geometry);
```

- Try a different band combination to compare.
- Turn on and delete the red rectangle in Geometry Tools.
- Repeat the steps in Section 3.1 and redraw a rectangle in your own area of interest and try running the script for some different band combinations.

2.3 Filtering the Sentinel-2 collection by date (video tutorial)

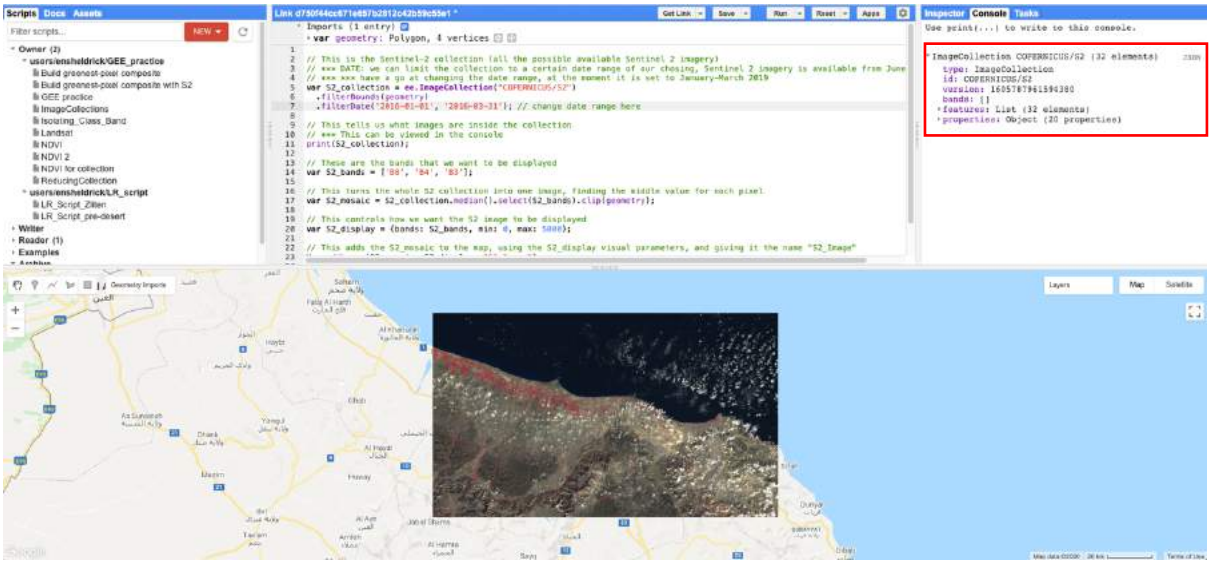
In our earlier scripts, we have created a mosaic using the entire Sentinel-2 collection, which contains hundreds of images from 2015 onwards. GEE allows us to define a date range that we are interested in and filter the imagery to only those dates. This is incredibly useful if we are analysing change to landscapes or archaeological sites over time and want to compare different time periods.

- Click here to open the next version of the script https://code.earthengine.google.com/d750f44cc671e657b2812c42b59c55e1
- Find the "DATE" section of the script in the Code Editor

```
Imports (1 entry)
  var geometry: Polygon, 4 vertices

// This is the Sentinel 2 collection (all the possible available Sentinel 2 imagery)
// *** DATE: we can limit the collection to a certain date range of our chosing, Sentinel 2 imagery is available from June 2
// *** *** have a go at changing the date range, at the moment it is set to January-March 2019
var S2_collection = ee.ImageCollection("COPERNICUS/S2")
  .filterBounds(geometry)
  .filterDate('2019-01-01', '2019-03-31'); // change date range here

// This tells us what images are inside the collection
// *** This can be viewed in the console
print(S2_collection);

// These are the bands that we want to be displayed
var S2_bands = ['B8', 'B4', 'B3'];

// This turns the whole S2 collection into one image, finding the middle value for each pixel
var S2_mosaic = S2_collection.median().select(S2_bands).clip(geometry);

// This controls how we want the S2 image to be displayed
var S2_display = {bands: S2_bands, min: 0, max: 5000};

// This adds the S2_mosaic to the map, using the S2_display visual parameters, and giving it the name "S2_Image"
Map.addLayer(S2_mosaic, S2_display, "S2_Image");

// This automatically pans the map to the middle of our area of interest
Map.centerObject(geometry);
```

The two dates in red text define the start and end of the filter range.

- These dates can be changed, but it is important to note that Sentinel-2 imagery was only produced from June 2015, so this is the earliest date that can be selected.
- Change the year to 2016 on both dates and click Run.
- Expand "ImageCollection" in the Console Window.



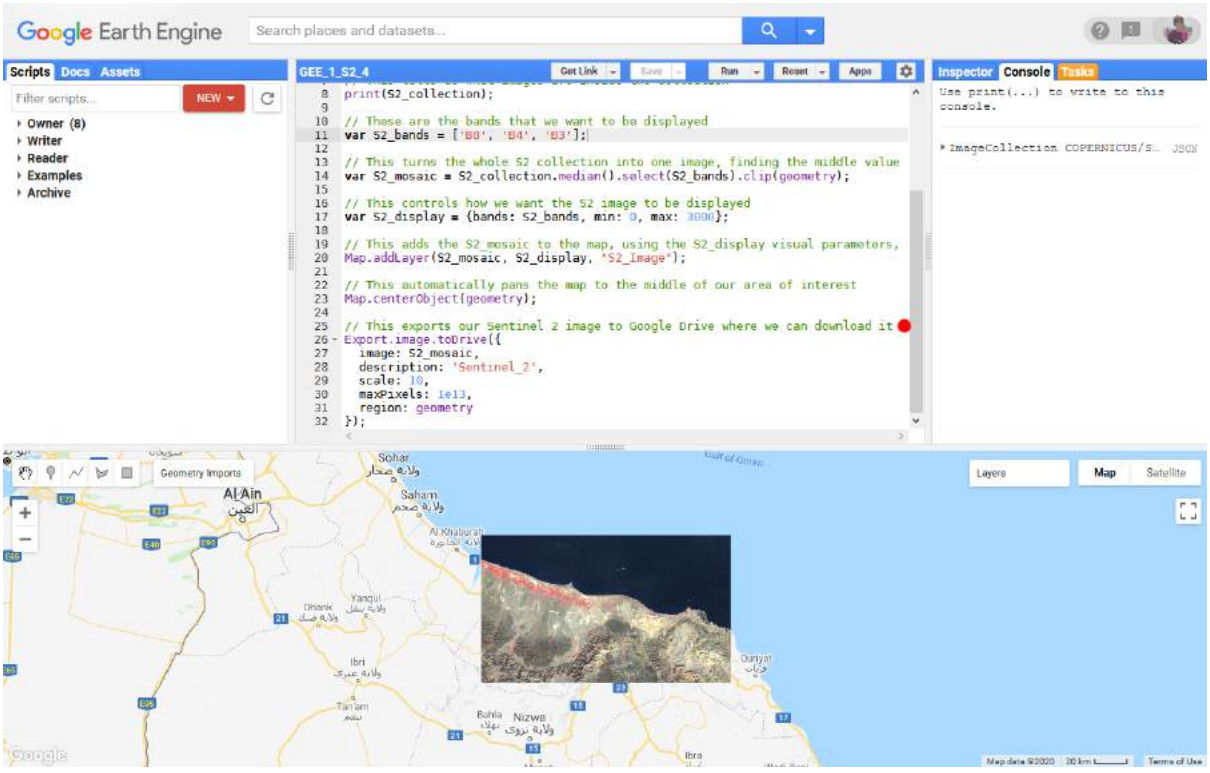
If you expand the 'features' section, it will tell you the details of each image in the collection based on the dates that you have given.

- Repeat the steps in Section 3.1 to define your own area of interest and try changing the date ranges.
- See if you can spot any changes in your area over time.

2.4 Exporting Sentinel-2 imagery to QGIS (video tutorial)

Having now used all the different parts of this simple Sentinel-2 script, we are now going to learn how to export the imagery into QGIS.

- Click here to open the final version of the script https://code.earthengine.google.com/d1e21be1c93d44d27376027173b14075
- Set your area of interest following the steps in Section 3.1.
- Choose a band combination that you are happy with as outlined in Section 3.2.
- Set the date filter to a useful range as described in Section 3.3.
- Run the script and make sure you are happy with the final image.
- Scroll down to the last section of the script in the Code Editor.

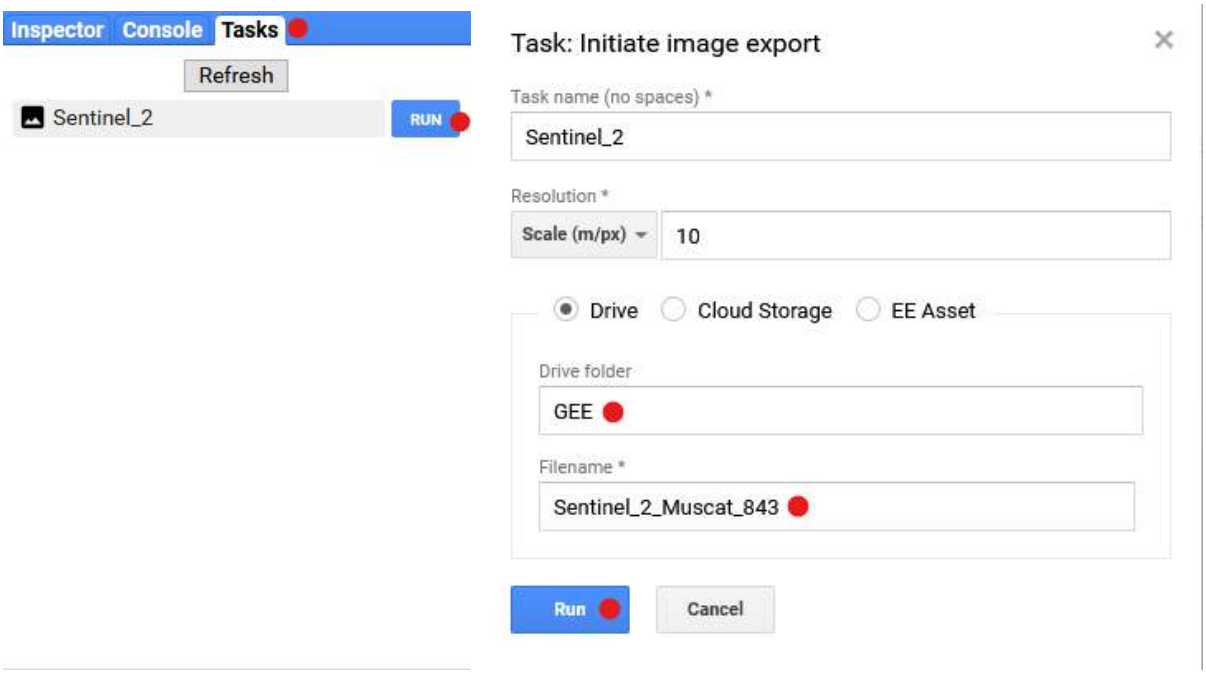


This section controls the export settings:

- image: tells the script which image to export (S2_mosaic),
- description: specifies the name of the export job (Sentinel_2),
- scale: specifies the resolution of the image (10m),
- maxPixels: defines the maximum number of pixels per image (1e13 = 10000000000000),
- region: specifies the area to be exported (geometry indicates that it should export the area defined by the red rectangle).

Unless you are exporting a very large image and want a lower resolution (e.g. 100 or 1000m), you can leave these settings as they are.

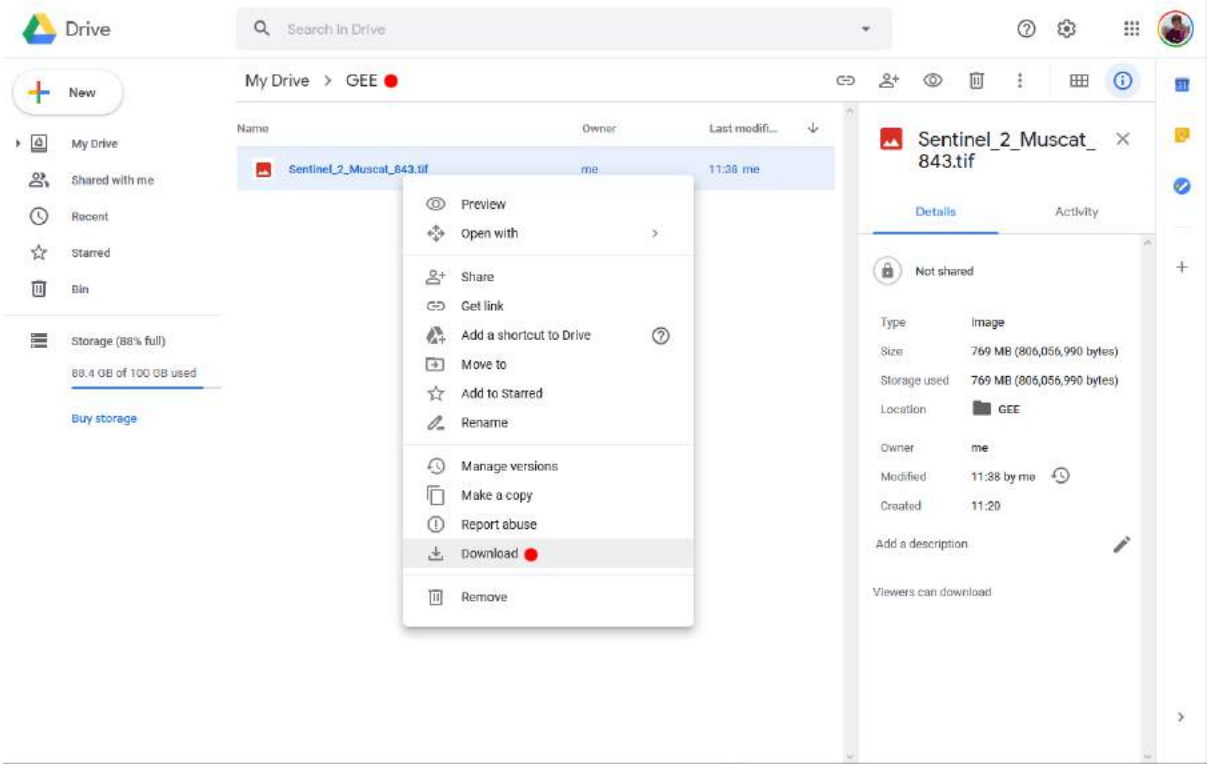
- In the Console window click the orange Tasks tab.
- Click the blue 'Run' button next to "Sentinel_2".
- Type "GEE" in "Drive folder".
- Give your Sentinel-2 image a name (including the general area and band combination is a good idea) and click Run.



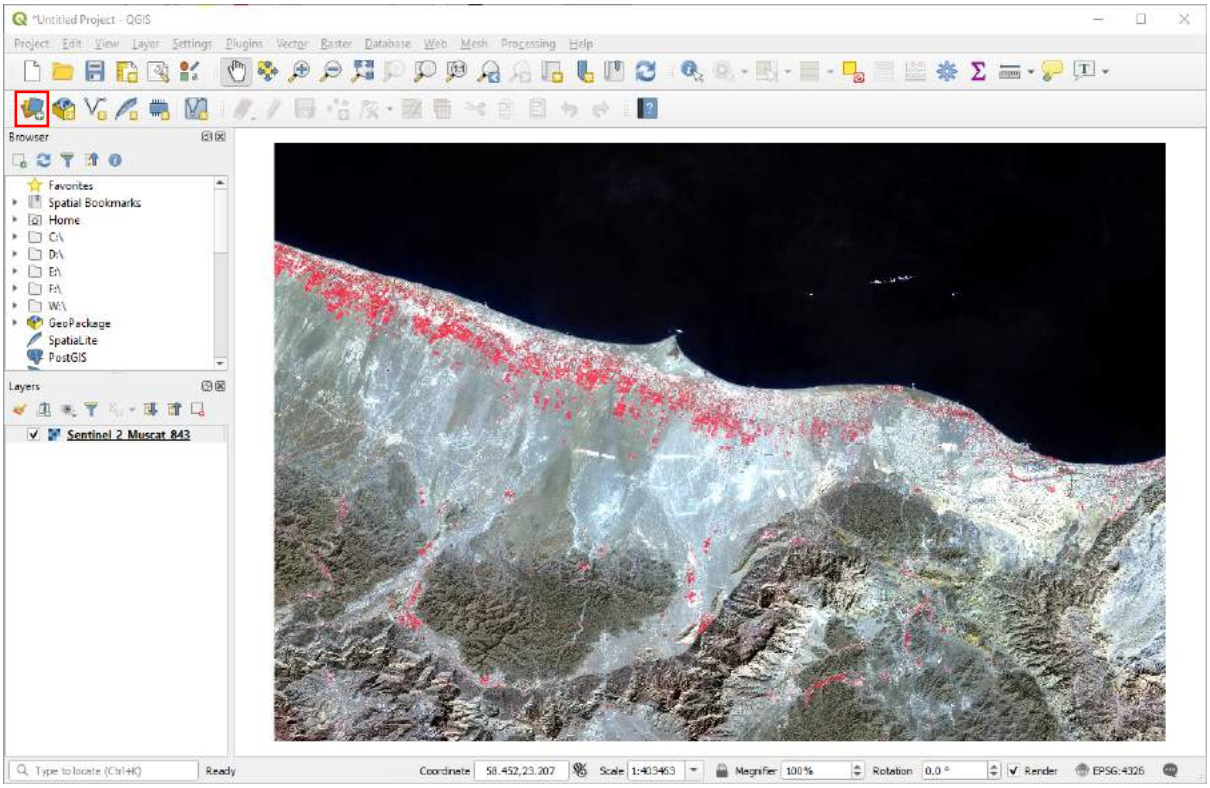
- Wait until the export completes in the Task window
  - While it is working it will show a cog and how long ago the task started,
  - When it is complete it will turn blue and show a tick mark
  - This may take a few minutes depending on the size of the image
- If it is taking a long time click the Refresh button, or the [?] that appears next to the small cog.

- Open a new tab and go to Google Drive https://drive.google.com/drive/u/0/my-drive
- Find and open your new GEE folder.

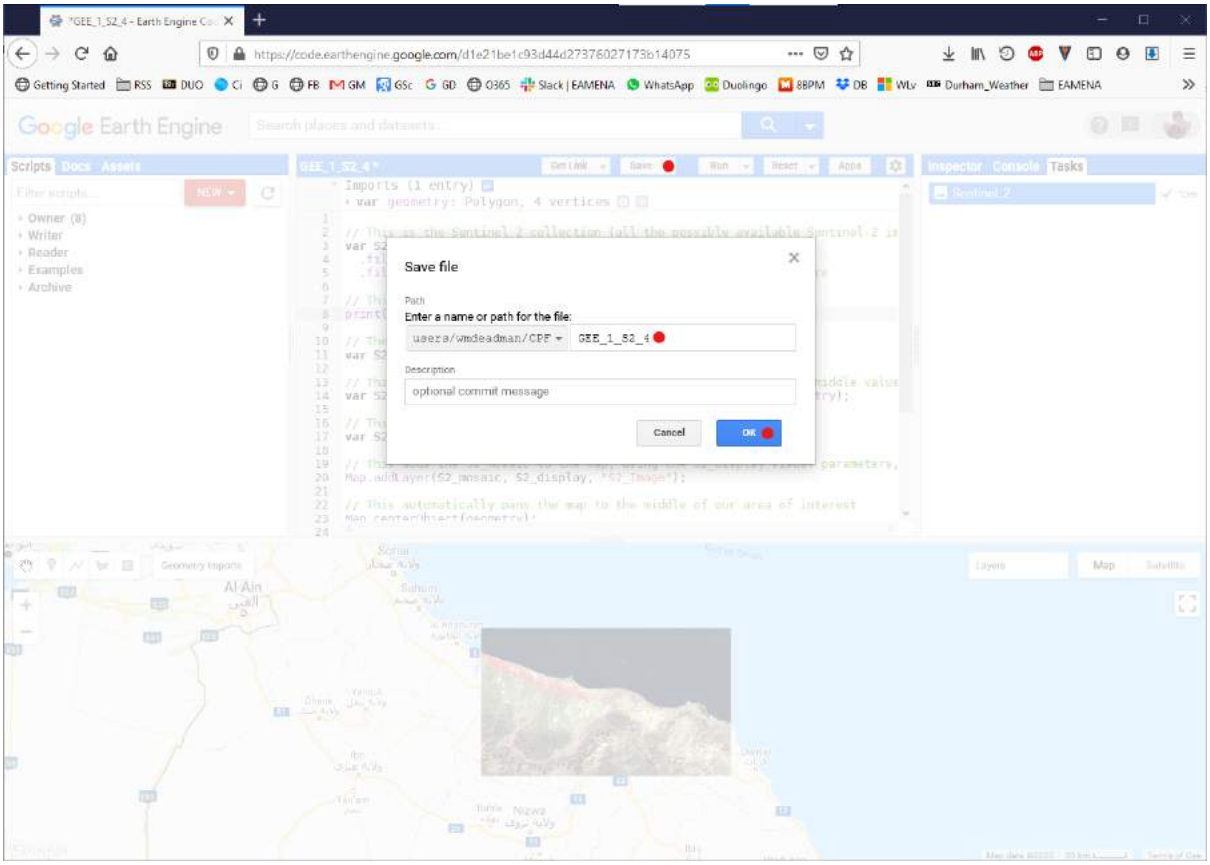
- Find your Sentinel-2 image, right click it and select Download.
- When the download has completed, move the image into your GIS folder and create a new folder for it (e.g. GEE).



- Open QGIS and add your Sentinel-2 image using the 'Open Data Source Manager' button on the Toolbar and choosing 'Raster'.
    - Navigate to your saved Sentinel-2 image file and click Add.



- Return to the GEE window to save your copy of the script so you can revisit it later.
- Click the black arow next to the Save button and select “Save As”.
- Give your script a name and click Save.



You can now access this script in your Scripts window.

PRACTICE: create and download a Sentinel-2 composite for your area of interest and incorporate it into a map in QGIS.

3 Working with Sentinel-2 and Landsat-5 Data (video tutorial playlist)

Sentinel-2 imagery is excellent for examining the most recent alterations to the landscape, but the imagery only goes back to June 2015. If we want to compare imagery over a longer time period, we need to include other imagery.

The Landsat-5 satellite collected very similar data to Sentinel-2 between 1984 and 2012. This is the perfect dataset for examining changes to the landscape over a long period of time. Our next script combines both Sentinel-2 and Landsat-5 data to provide a comparison between modern and historical imagery.

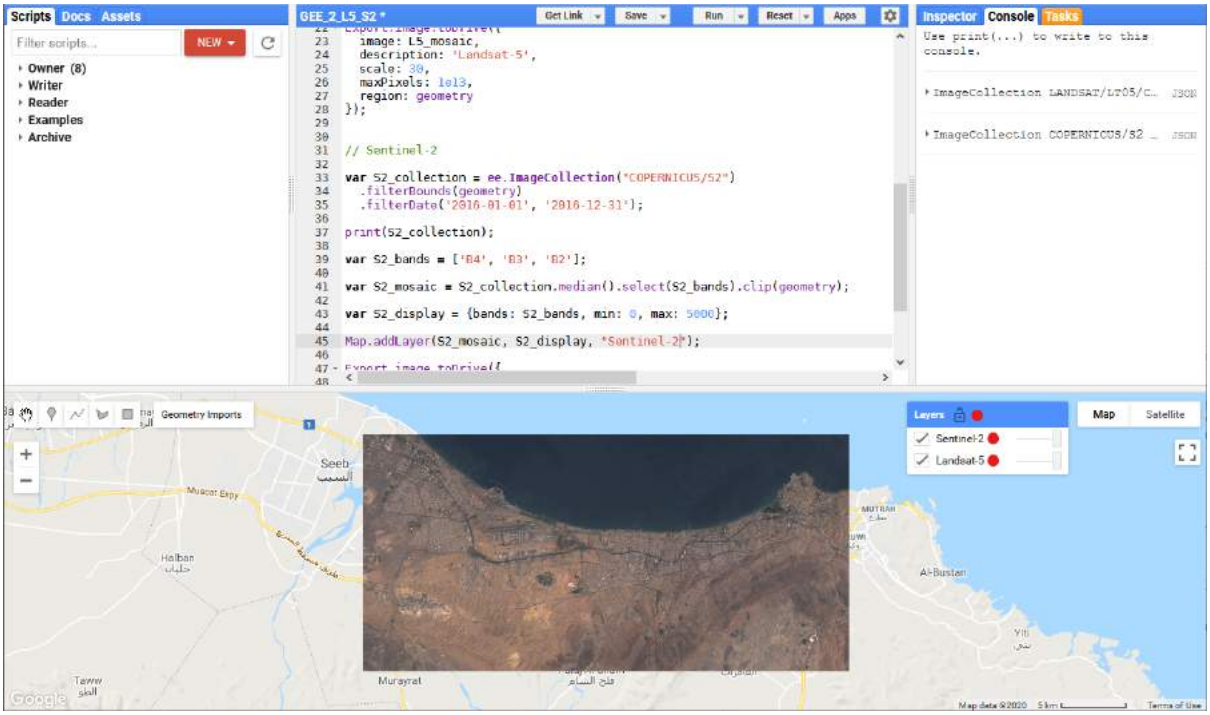
3.1 The Layers Panel and defining your area of interest (video tutorial)

First, we are going to open the script, explore the two different layers and define a new area of interest.

- Click here to open the new script: https://code.earthengine.google.com/1132354830d01200e6e064cafd4c4f95

- Hover your mouse over the Layers Panel (on the upper right side of the Map View).

Notice that two layers are now being displayed in the Map View Window – the Sentinel-2 image above and the Landsat-5 below.



- Turn off the Sentinel-2 image by clicking on the check beside it and zoom into the imagery to compare the two datasets.
- Delete the old red rectangle and define a new area of interest with the Geometry Tools following the instructions in Section 3.1.
    - Compare the two different types of imagery for your area.

3.2 Filtering the Sentinel-2 and Landsat-5 collections by date (video tutorial)

To get the most out of this script we want to be able to set the dates of the imagery to follow our own parameters.

You should notice that this new script is very similar to the previous one, except that it now contains two parts –one for the Landsat-5 imagery and one for the Sentinel-2 imagery. The basic commands are almost identical for both datasets, and to the previous script that we looked at.

```
3  //Landsat 5 (1984-2012)
4
5  var L5_collection = ee.ImageCollection("LANDSAT/LT05/C01/T1_TOA")
6    .filterBounds(geometry)
7    .filterDate('1995-01-01', '1995-12-30')
8    .filter(ee.Filter.lt("CLOUD_COVER", 0.1)); //this new command removes cloudy images
9
10 print(L5_collection);
11
12 var L5_mosaic = L5_collection.median().clip(geometry);
13
14 var L5_bands = ["B3", "B2", "B1"];
15
16 var L5_display = {bands: L5_bands, min: 0, max: 0.5};
17
18 Map.addLayer(L5_mosaic, L5_display, "Landsat-5");
19
20 Map.centerObject(geometry);
21
22 Export.image.toDrive({
23   image: L5_mosaic,
24   description: 'Landsat-5',
25   scale: 30,
26   maxPixels: 1e13,
27   region: geometry
28 });
29
30
31 // Sentinel-2
32
33 var S2_collection = ee.ImageCollection("COPERNICUS/S2")
34   .filterBounds(geometry)
35   .filterDate('2016-01-01', '2016-12-31');
36
37 print(S2_collection);
38
39 var S2_bands = ['B4', 'B3', 'B2'];
40
41 var S2_mosaic = S2_collection.median().select(S2_bands).clip(geometry);
42
43 var S2_display = {bands: S2_bands, min: 0, max: 5000};
44
45 Map.addLayer(S2_mosaic, S2_display, "Sentinel-2");
46
47 Export.image.toDrive({
48   image: S2_mosaic,
49   description: 'Sentinel-2',
50   scale: 10,
51   maxPixels: 1e13,
52   region: geometry
53 });
54
```

To get the widest possible comparison we are going to change the dates to 1984 and 2020 for the Landsat-5 and Sentinel-2 imagery respectively.

- On line 7 of the script, in the Landsat section, change both years to 1984.
- On line 35 of the script, in the Sentinel-2 section, change both years to 2020.
- Run the script.
- Try entering different dates and look for evidence of change between the two images.

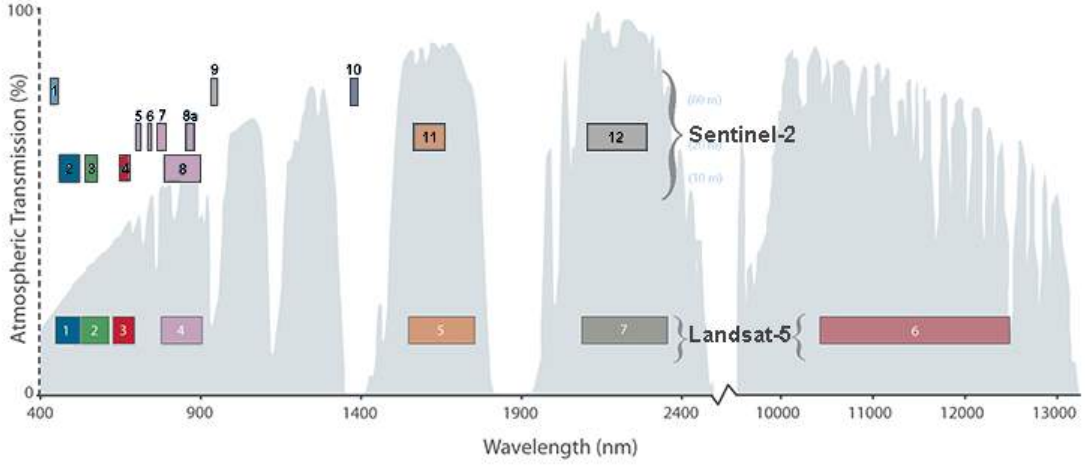
3.3 Creating Sentinel-2 and Landsat-5 colour composites (video tutorial)

We also want to be able to create our own colour composites with different band combinations, but we must be careful to make sure that the Sentinel-2 and Landsat-5 versions match.

- Have a look at the Sentinel-2 and Landsat-5 bands in the Code Editor and the two sets of imagery in the Layer Panel.

```
var L5_bands = ["B3", "B2", "B1"]; var S2_bands = ['B4', 'B3', 'B2'];
```

Even though both images are True Colour Composites, the band combinations are slightly different. This is because the instruments on board the Sentinel-2 and Landsat-5 satellites are not identical – different bands focus on different parts of the electromagnetic spectrum.



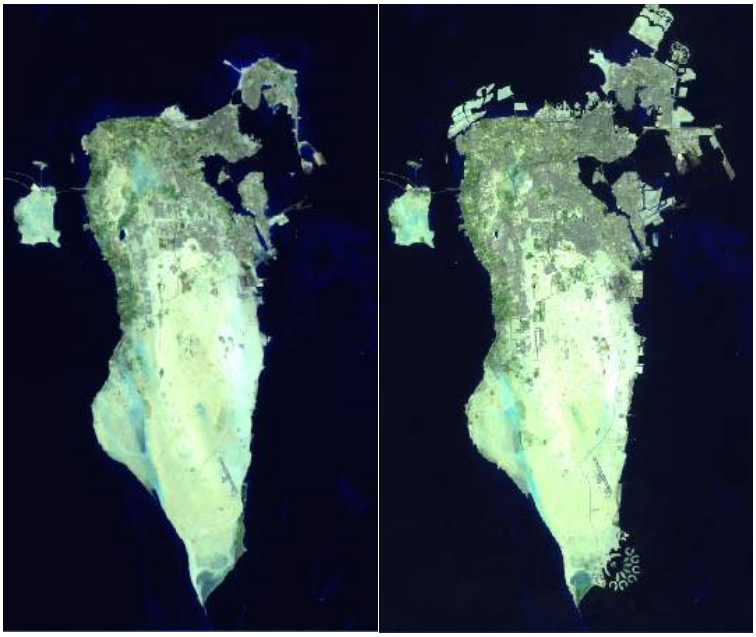
This means that care must be taken when programming the bands into the script – if you use the same numbers for each image, then you will end up with very different looking colour composites.

The following table provides equivalent band combinations for both datasets. It also provides guidance on possible applications for each band combination.

Composite	Sentinel-2	Landsat-5	Applications
natural colour	4/3/2	3/2/1	general - recognisable to the naked eye
natural-like	12/8/3	7/4/2	general - recognisable but clearer than natural colour
colour infrared	8/4/3	4/3/2	agricultural areas (bright red)
false colour (agriculture)	11/8/2	5/4/1	agricultural areas (bright green)
false colour (urban)	12/11/4	7/5/3	urbanisation
false colour (land/water)	8/11/4	4/5/3	coastal and wetland areas
false colour (geology 1)	12/11/2	7/5/1	desertification, mining and industry
false colour (geology 2)	11/3/2	5/2/1	desertification, mining and industry

- Set the Sentinel-2 and Landsat-5 bands to produce a colour infrared composite.
- Run the script and compare the Sentinel-2 and Landsat-5 images.

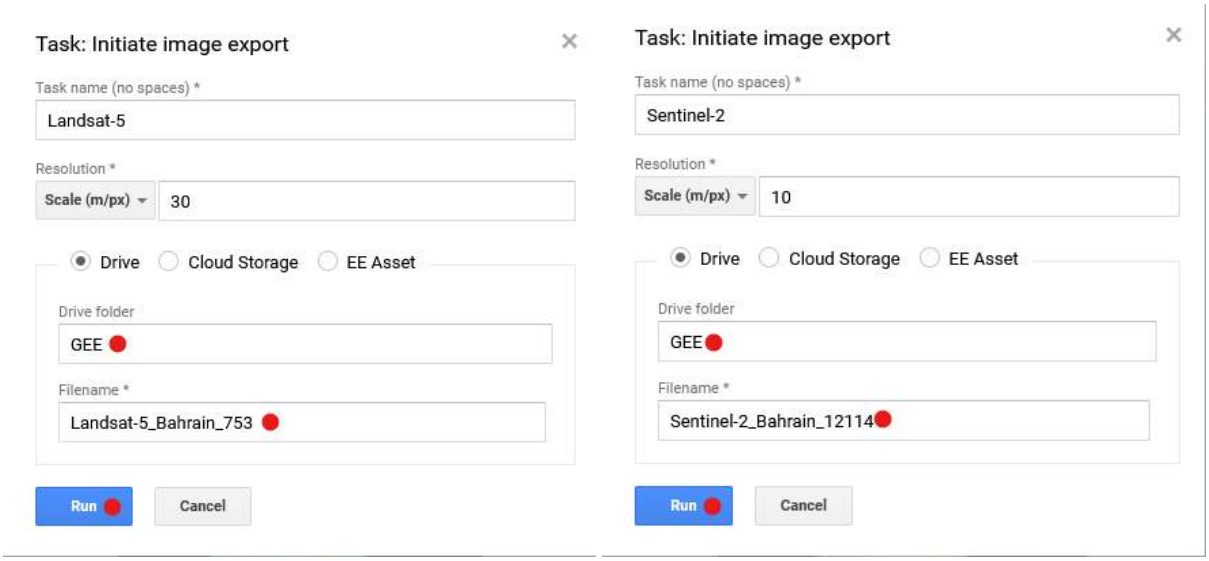
- If you haven't already, change the area of interest to your area
- Change the band combinations to a combination that is relevant to your area and run the script.



3.4 Exporting Sentinel-2 and Landsat-5 imagery (video tutorial)

Once you are happy with the area, date and band combinations used in your Landsat-5 and Sentinel-2 imagery both can be exported.

- Make sure you are happy with the area of interest, date and band combinations that you have chosen following the steps in the previous sections and run your script.
- Click on the Tasks Window.
- Click "Run" next to "Landsat-5".
- Type "GEE" in "Drive Folder".
- Give it an appropriate name including the area and band combination and click Run.
- Repeat this for your Sentinel-2 image – both can run at the same time.

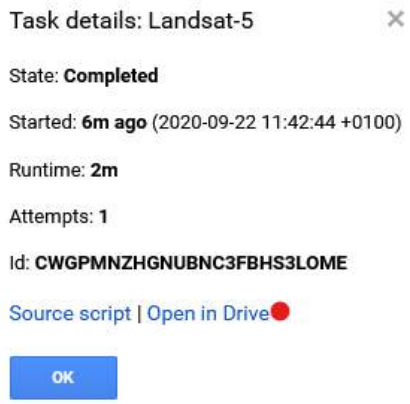


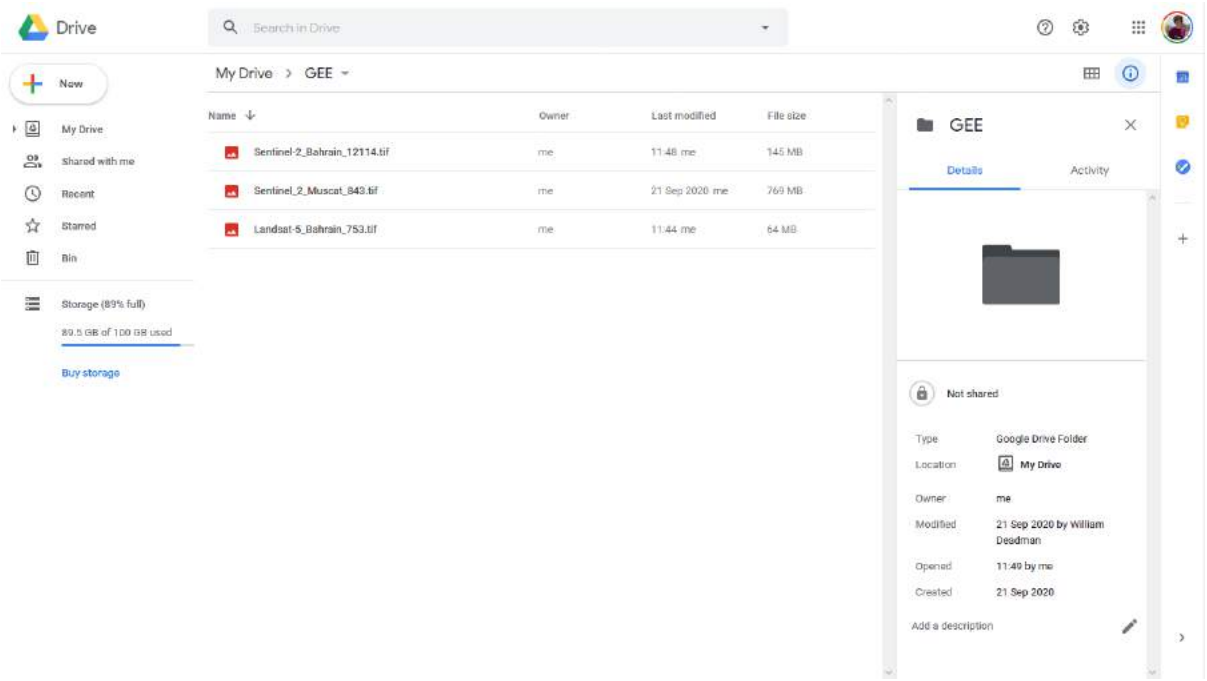
Once completed you can download them from Google Drive to open in QGIS using the steps explained earlier.

There is also a shortcut for getting to the image easily.

- Hover your mouse over a completed image in the Tasks window and click the [?] button

- Click "Open in Drive"





- Right-click your images and click "Download" to download them.
- When completed, move them from your Downloads folder to your GIS/GEE folder.
- Open and browse your images in QGIS.
- Don't forget to save your script if you want to revisit it in the future (the "Save" arrow > "Save As").

ACTIVITY: create one or more maps in QGIS using false colour composites from GEE to illustrate changes in the landscape that have disturbed or that threaten archaeological sites in your area of interest.