Endangered Archaeology in the Middle East & North Africa

GIS TUTORIAL 6: Automatic Change Detection with GEE

In this tutorial we will be using a Google Earth Engine script designed to automatically detect changes that occur to areas in and around archaeological sites. "Automatic Change Detection" will be abbreviated to "ACD" for the rest of this tutorial.

1 ACD for site polygons around Madaba, Jordan (video tutorial playlist)

As well as using Google Earth Engine for simple things such as creating colour composites of satellite imagery, it can also be used to carry out much more complex tasks such as ACD.

1.1 Introduction to the ACD script (video tutorial)

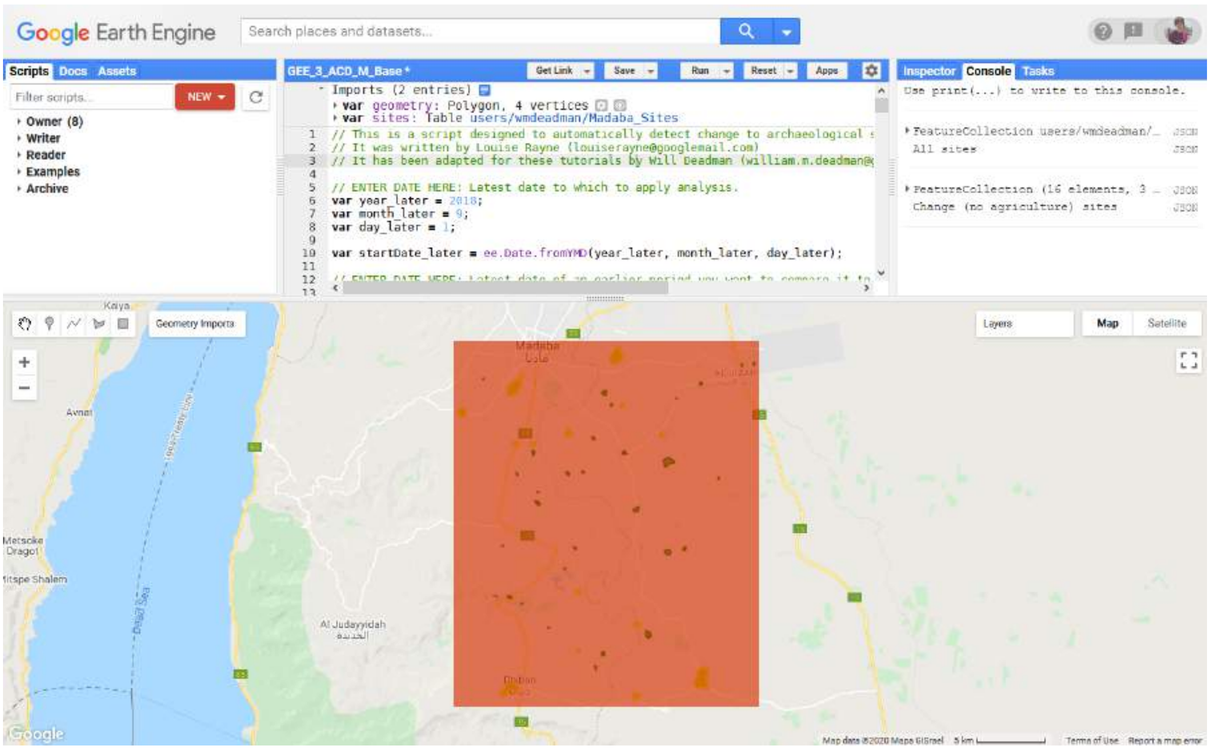
The script we will be using has been developed by the EAMENA project to automatically detect change to areas surrounding archaeological sites. This will help to monitor sites and rapidly identify threats.

It works by creating one earlier and one later Sentinel-2 composite and then mathematically comparing each band, highlighting areas where there are significant differences, and then checking which archaeological sites might be threatened.

- Click here to open the script in your web browser : https://code.earthengine.google.com/2001fd7a6f790d310750cff9b7e8bd65

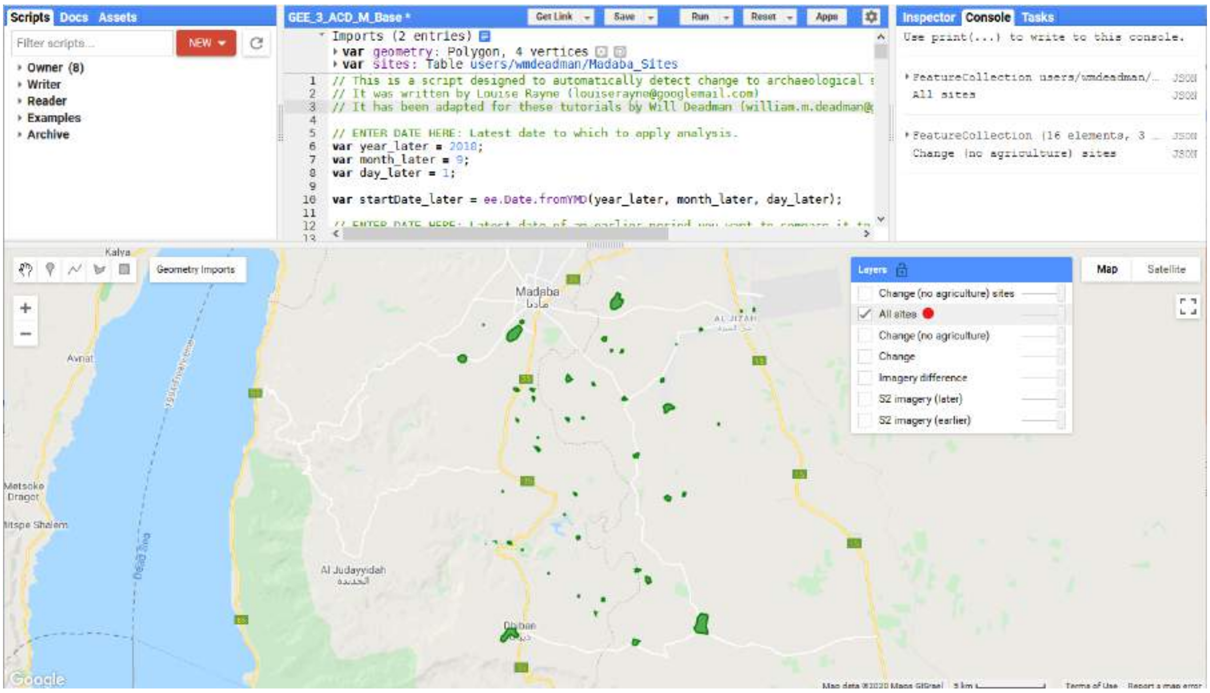
This version of the script is set up to run ACD on a dataset of 50 sites southeast of Madaba in Jordan. We are going to use this example dataset to familiarise ourselves with some of its components and outputs.

- Turn on "Geometry" in the 'Geometry Imports' menu beside the Geometry Tools



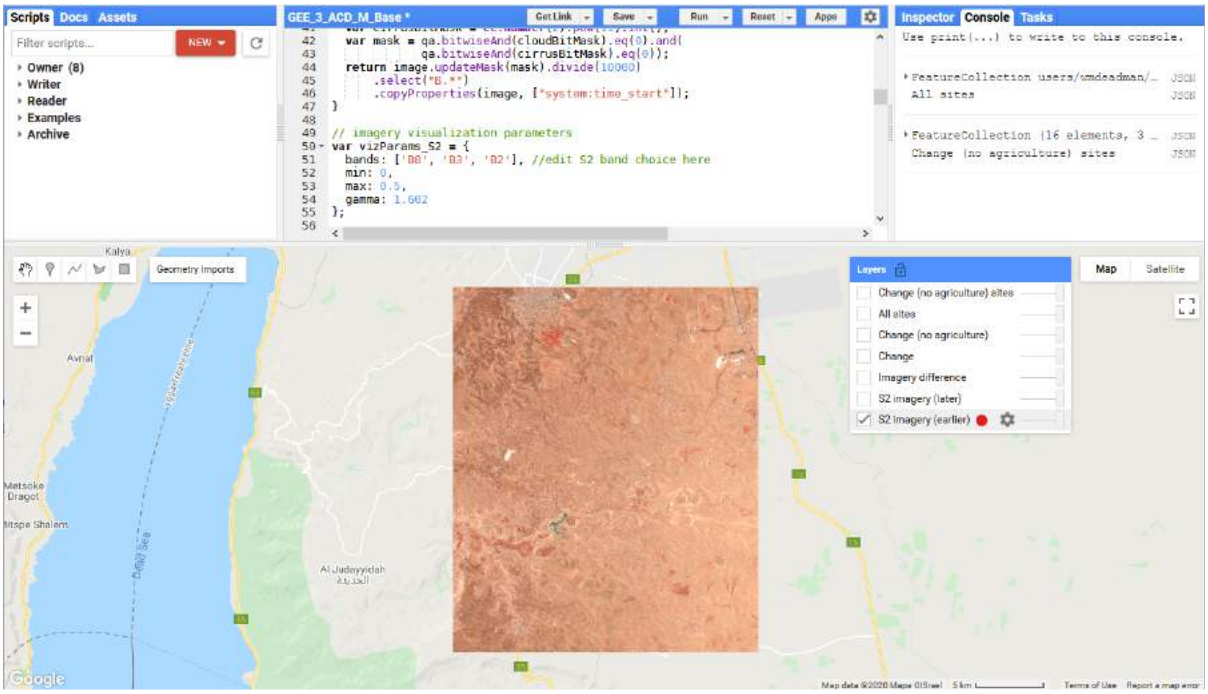
This is the area that we will be looking at.

- Turn off "Geometry" and in the Layers Panel turn off all the layers except "All sites".



These green polygons are the 50 sites we will be running the script with.

- Turn off "All sites" and turn on "S2 imagery (earlier)" in the Layers Panel.



This is the earlier Sentinel-2 composite that we will be using.

- Scroll down to lines 12-15 of the script

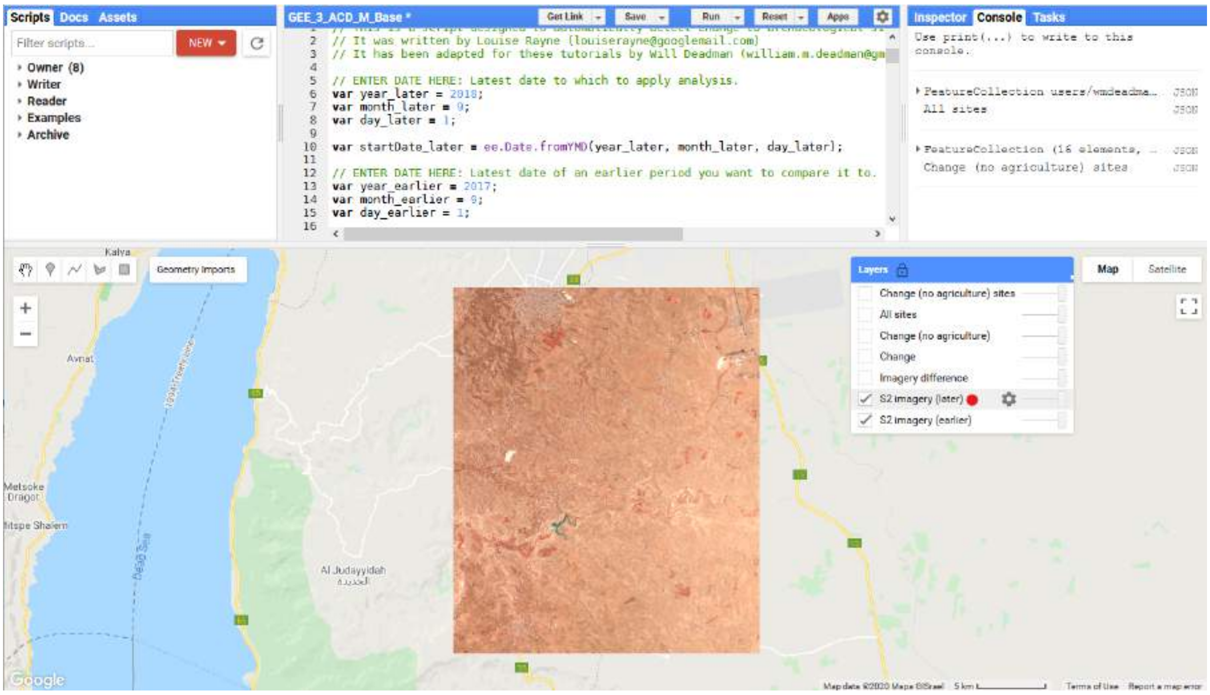
```
12  // ENTER DATE HERE: Latest date of an earlier period you want to compare it to.
13  var year_earlier = 2017;
14  var month_earlier = 9;
15  var day_earlier = 1;
```

- Then look at line 24

```
24 var delta_earlier = -3;
25 var unit_earlier = 'month';
```

These two lines control the date of the earlier image. In this version of the script, we have specified that we want this period to include Sentinel-2 data from 01/09/2017 and the three months before this date (i.e., back to 01/06/2017).

- Turn on "S2 Imagery (later)" in the Layers Panel



- See if you can spot any differences between the two images.

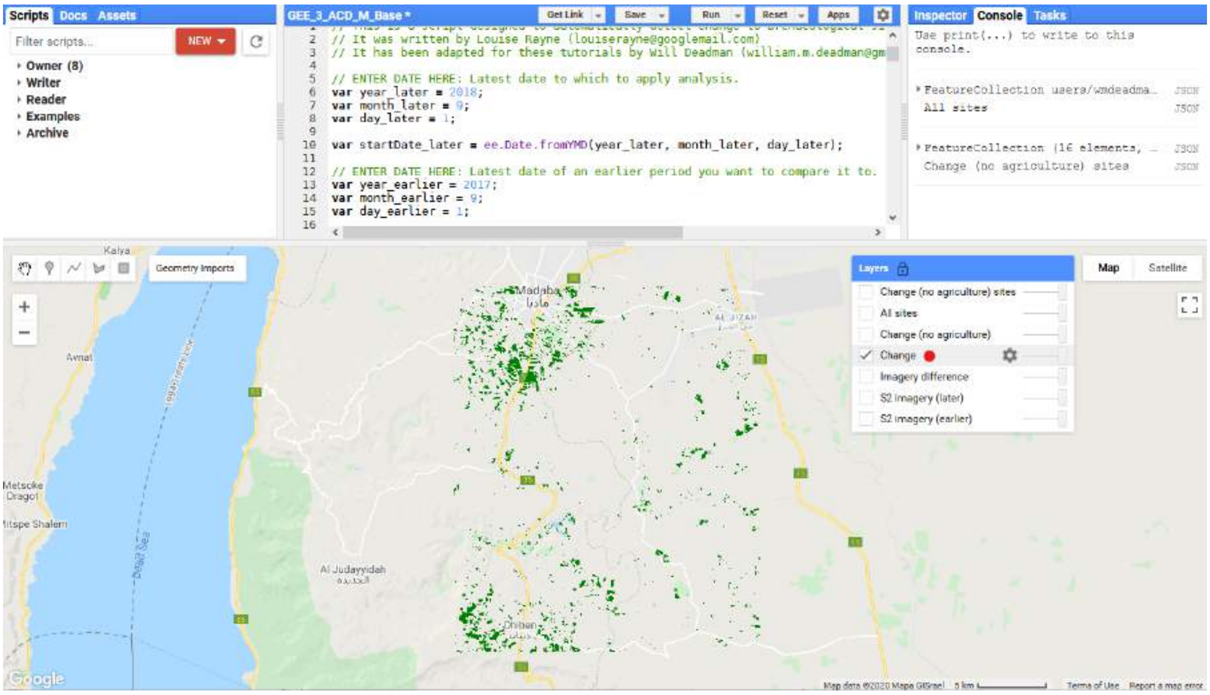
The date of this image is controlled in lines 5-8 and 21 of the script in the same way as in the earlier image.

Therefore, this version of the script will compare imagery from June to August 2017 and June to August 2018.

It is often useful to compare the same time of year to help reduce the effect of seasonal differences in the imagery (unless, of course, you are trying to investigate seasonal change).

- Turn off both Sentinel-2 images in the Layers Panel and turn on the "Change" layer.

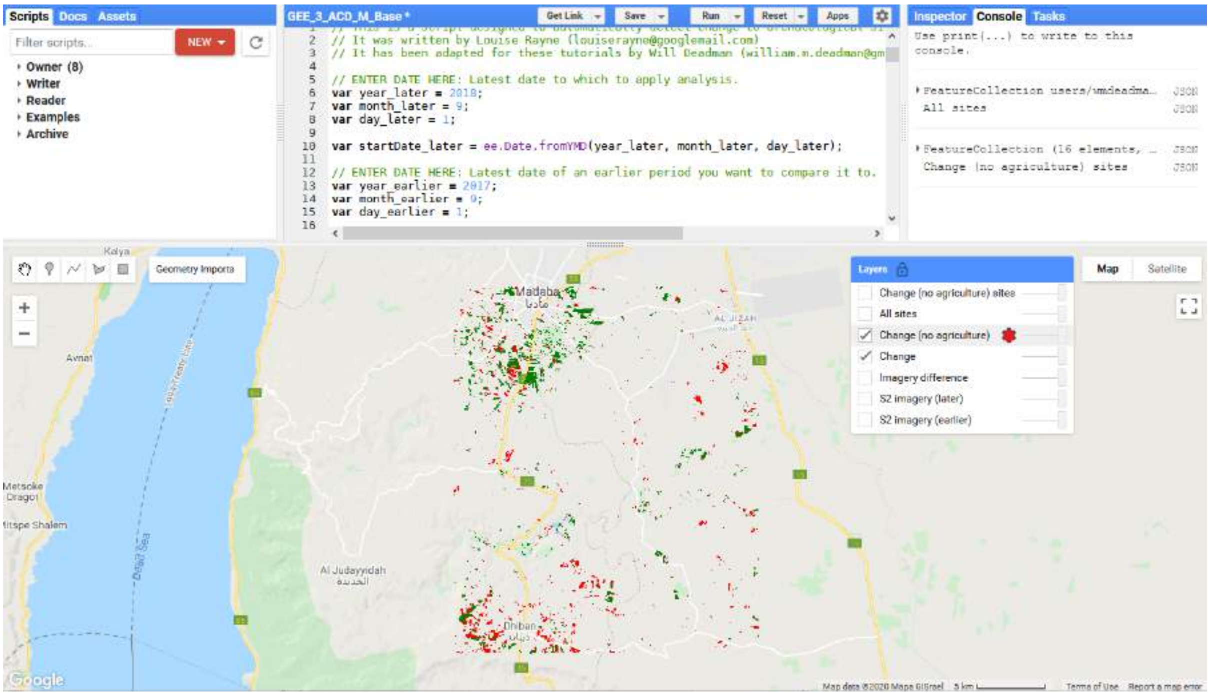
This shows the areas of the two images that mathematically show a significant difference (up to a threshold that we can set in the script).



If you zoom in and look around these areas of change, you will notice that many of them relate to agriculture – fields that had crops in during 2017 but not 2018 or vice versa.

However, this might hide other more significant types of change – such as building, mining or bulldozing, so we want to remove these areas.

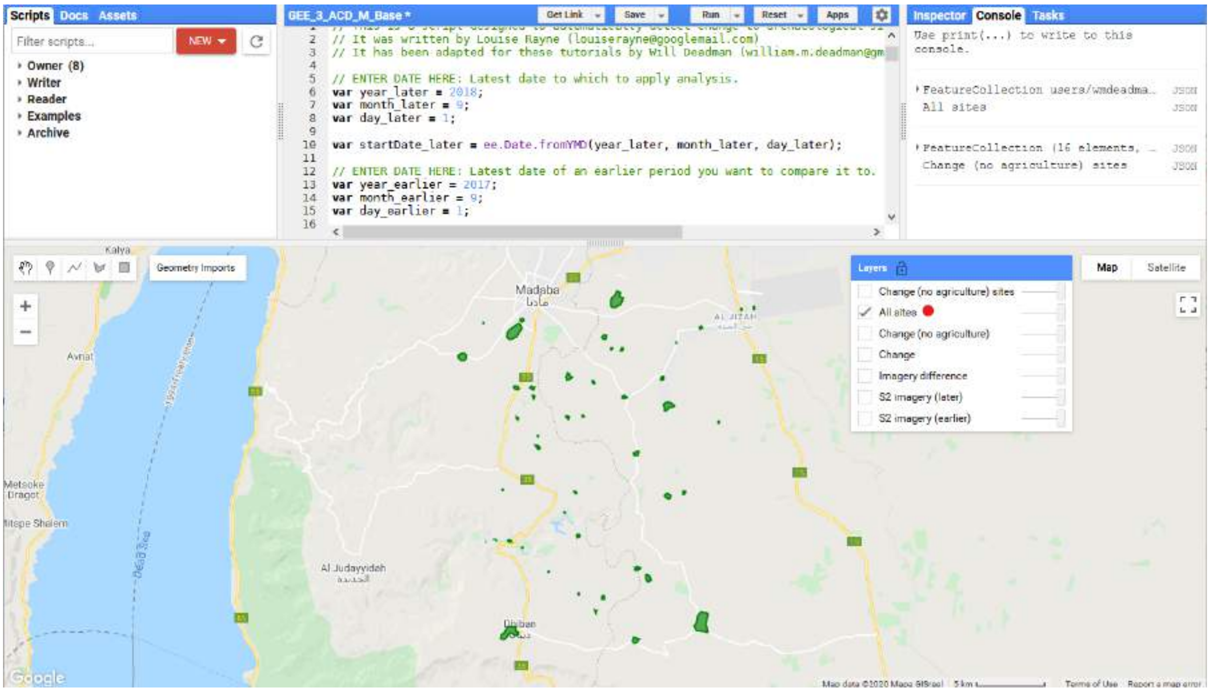
- In the Layers Panel turn on “Change (no agriculture)” and allow it to load.



Notice that for the new red layer, many of the big field-shaped areas have been removed. The script does this by finding and removing areas that frequently change between lots of vegetation and no vegetation (i.e. fields).

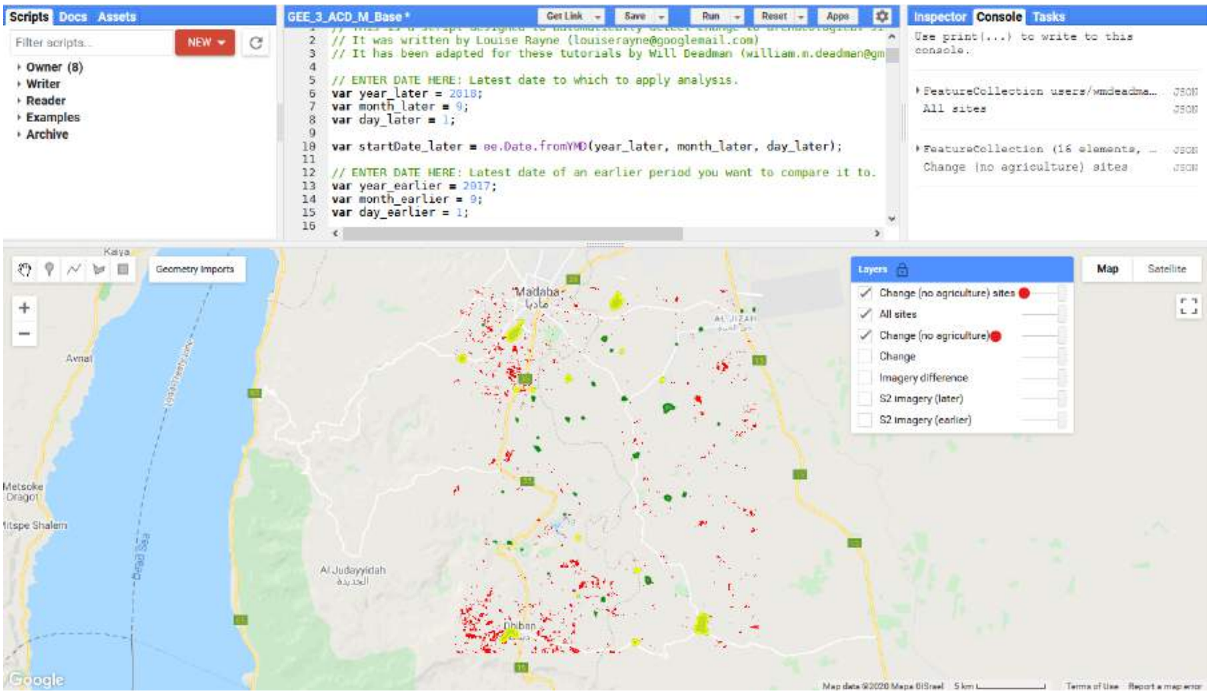
This red "Change (no agriculture)" layer is what we will use to compare to the archaeological site distribution.

- In the Layers Panel turn off the two change layers and turn on "All sites".



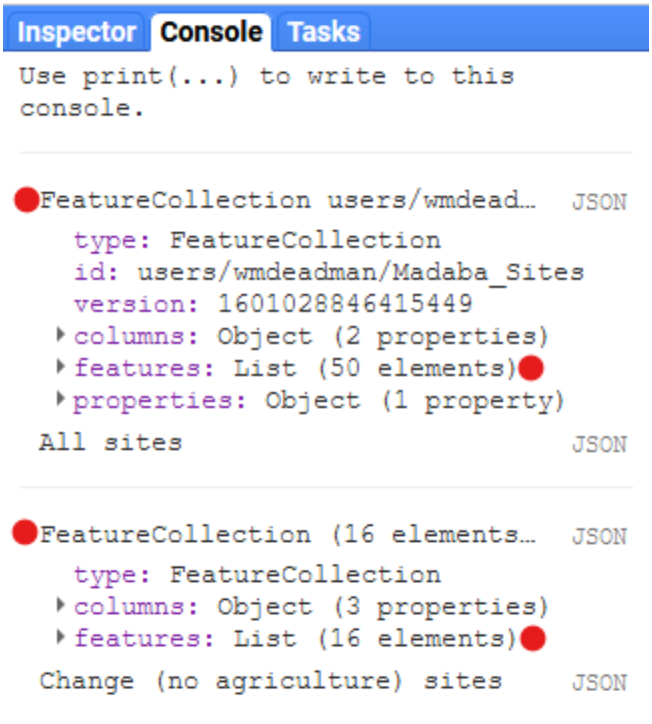
These are the fifty sites that we are going to check for changes.

- Turn the "Change (no agriculture)" and "Change (no agriculture) sites" layers on



Where there are red areas of change within the boundaries of an archaeological site the script selects it – these are the yellow polygons.

- Have a look at the console and expand the two "FeatureCollections"



You should see that there are 50 sites ("All sites") and that 16 of these overlapped with the red "Change (no agriculture)" areas ("Change (no agriculture) sites").

1.2 Exporting the ACD results (video tutorial)

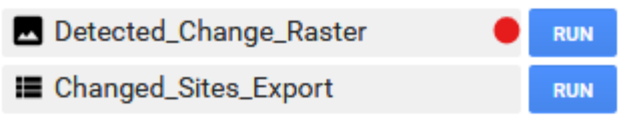
Now that we have run the script and understand how it works, we now need to export the results so that we can check using satellite imagery whether we can find any evidence for disturbances or other changes around these sites.

We have to check the results manually, because while the ACD script can identify if change has occurred around a site, it cannot reliably identify what those changes are and whether they are all important or relevant for our purposes.

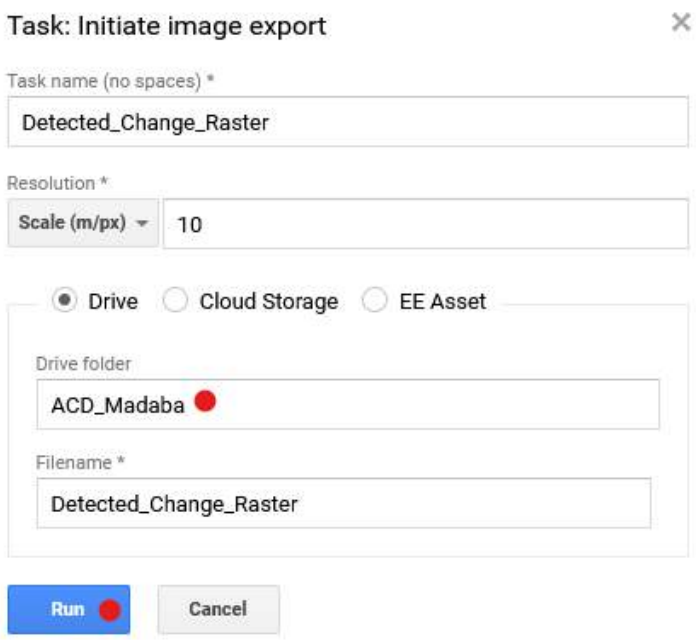
Make sure that the 'Change (no agriculture) sites' layer (the yellow polygons) has loaded completely and then click on the Tasks Window.

We are going to export the red "Change (no agriculture)" layer as a raster to show where change has occurred and the 16 sites where change has been identified at archaeological sites as a shapefile.

- Click "Run" next to "Detected_Change_Raster"

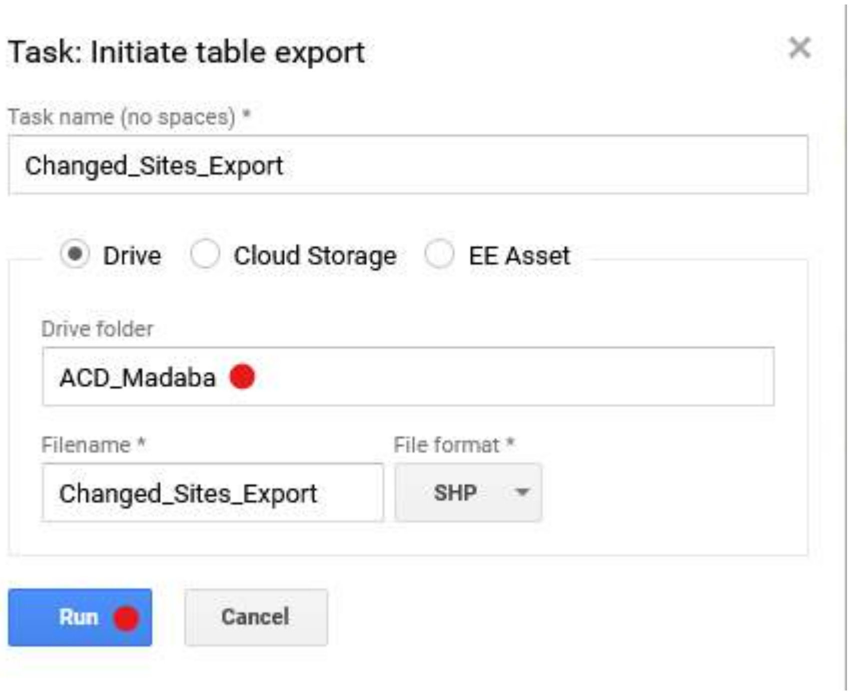


- For “Drive folder” type “ACD_Madaba” and click “Run”

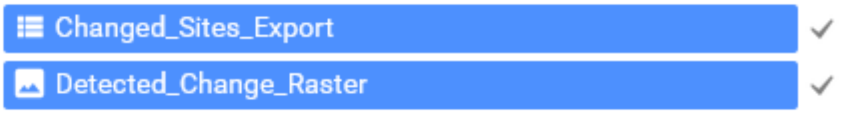


- Click “Run” next to “Changed_Sites_Export” in the Tasks Window

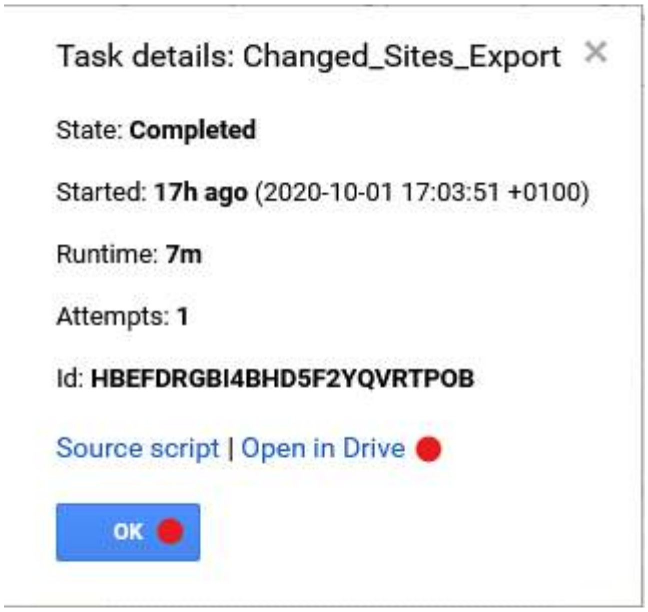
- Type “ACD_Madaba” in the “Drive Folder” field and click “Run”



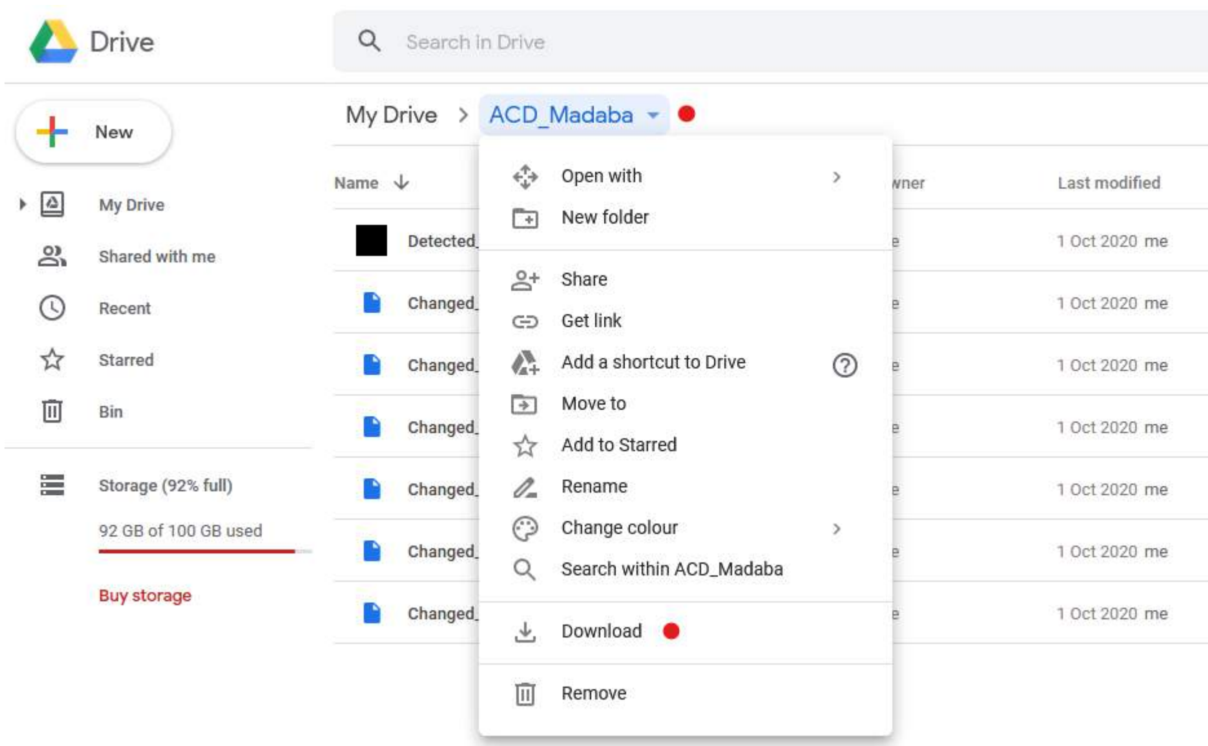
- Wait for these tasks to finish in the Task Window.
    - This may take several minutes.



- Click on the question mark on the right of "Changed_Sites_Export" in the Task Window
- Click "Open in Drive"

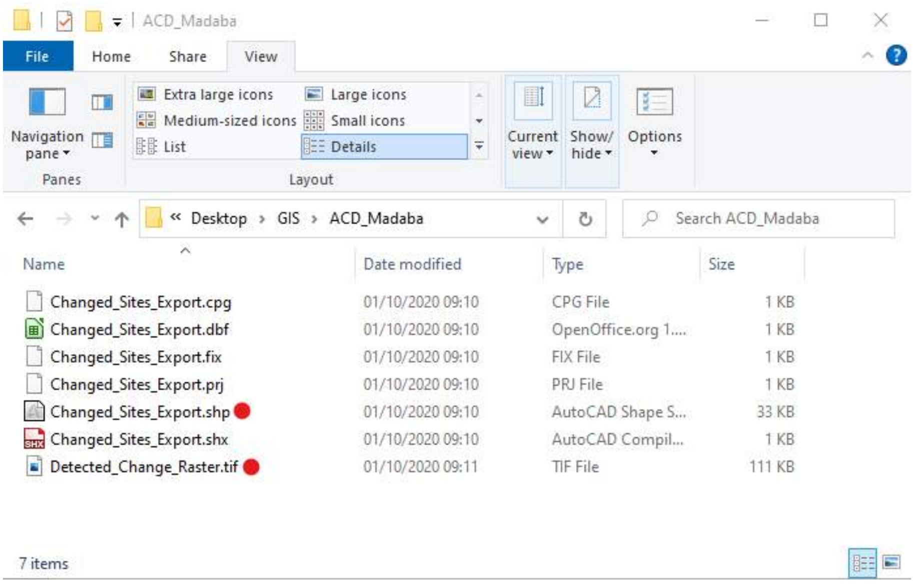


This will open the "ACD_Madaba" folder in which you saved both files in Google Drive.



- Click the small arrow next to the "ACD_Madaba" folder and click "Download".

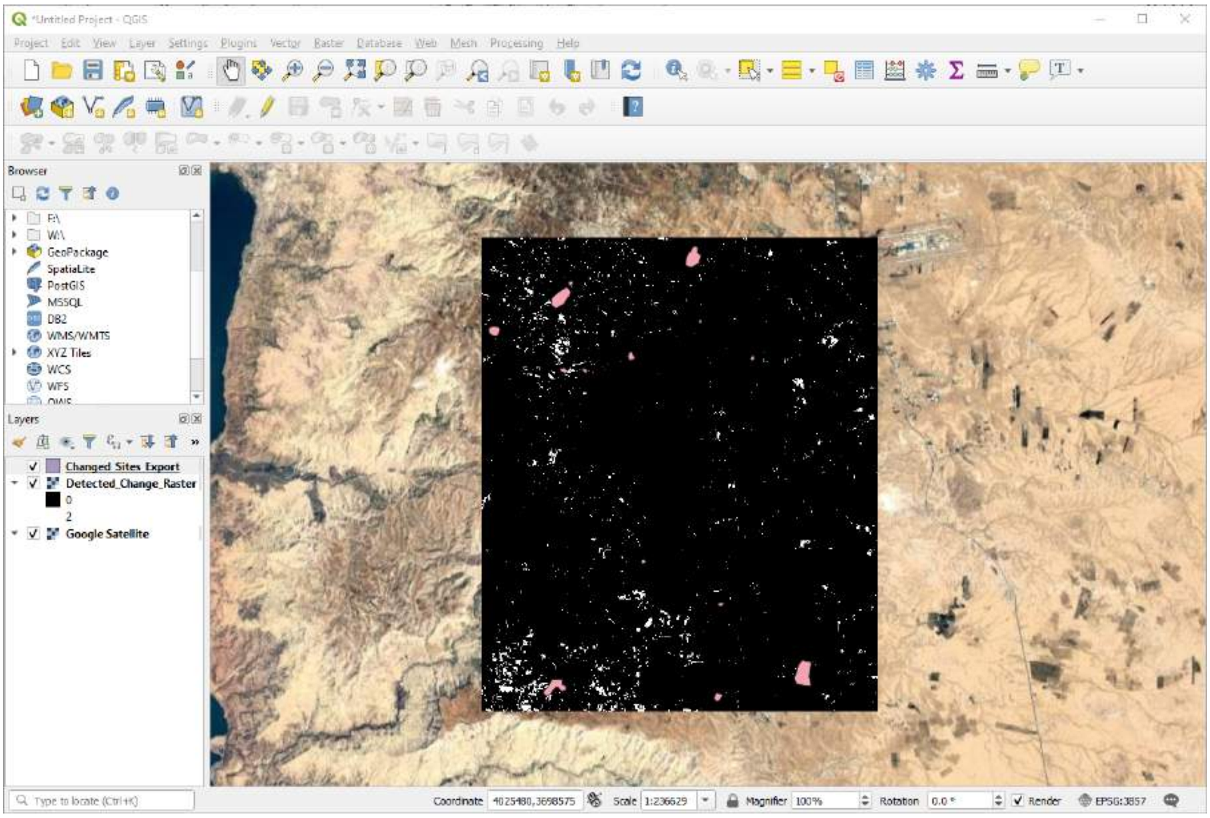
- Move this zip file from your Downloads folder to your GIS folder.
- Right-click the zip file and click “7-Zip” > “Extract Here” (or use any other unarchiving software you have).
- Open the new “ACD_Madaba” folder and make sure your shapefile and raster are there.



1.3 Opening the ACD results in QGIS and Google Earth (video tutorial)

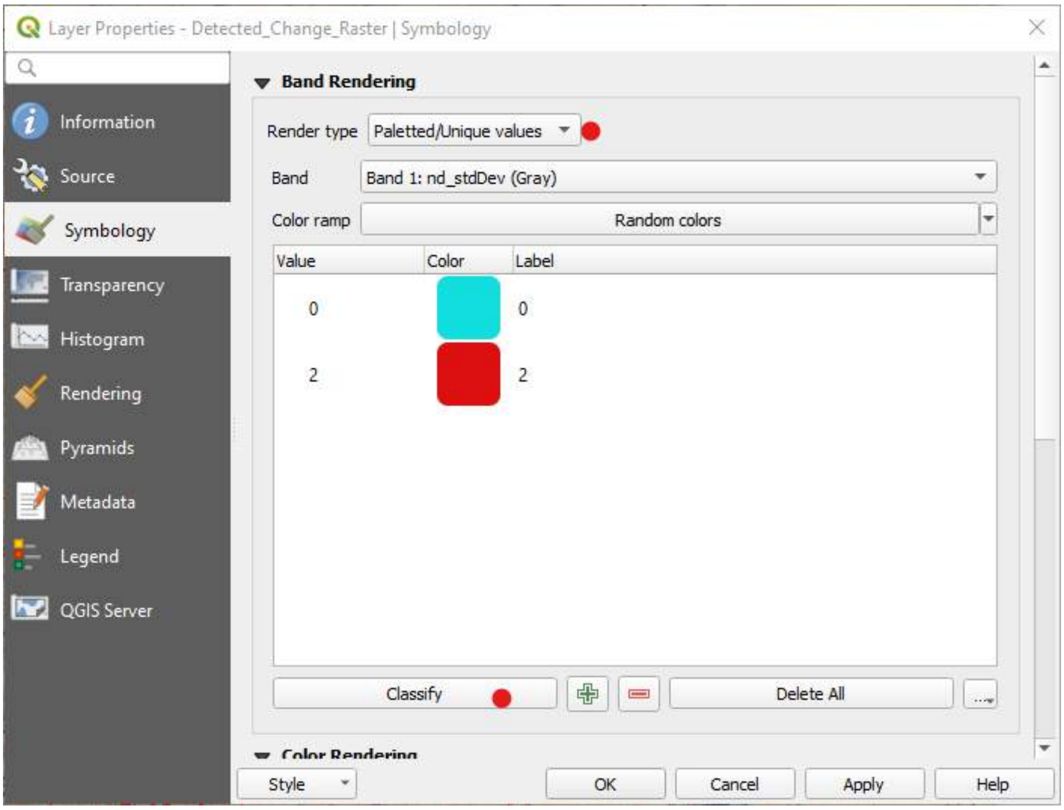
In order to check our results to see if the changes that have been detected by the script represent visible disturbances to the sites, we need to add them to QGIS and Google Earth.

- Open QGIS and start a new project.
- Add a satellite imagery XYZ Tiles basemap (Google or Bing) from the Browser Panel.
- Use the Open Data Source Manager on the Toolbar to add the “Detected_Change_Raster” geotiff and the “Changed_Sites_Export” shapefile.

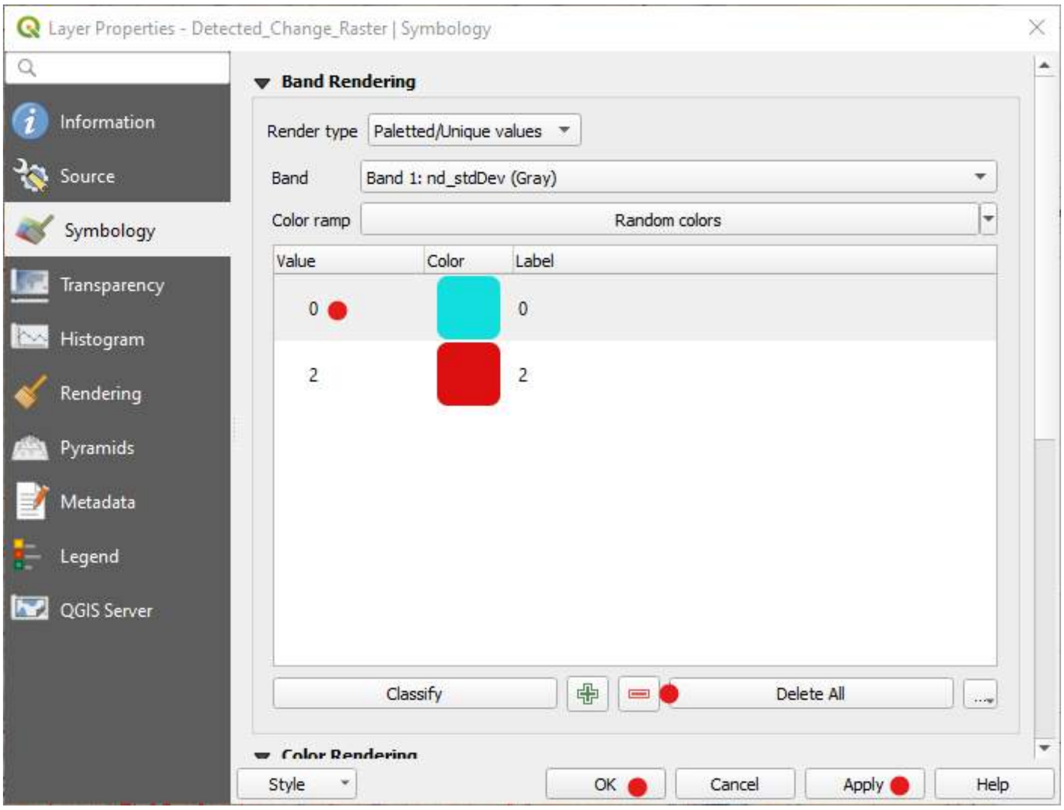


We need to remove the black background from the raster so we can see the satellite imagery.

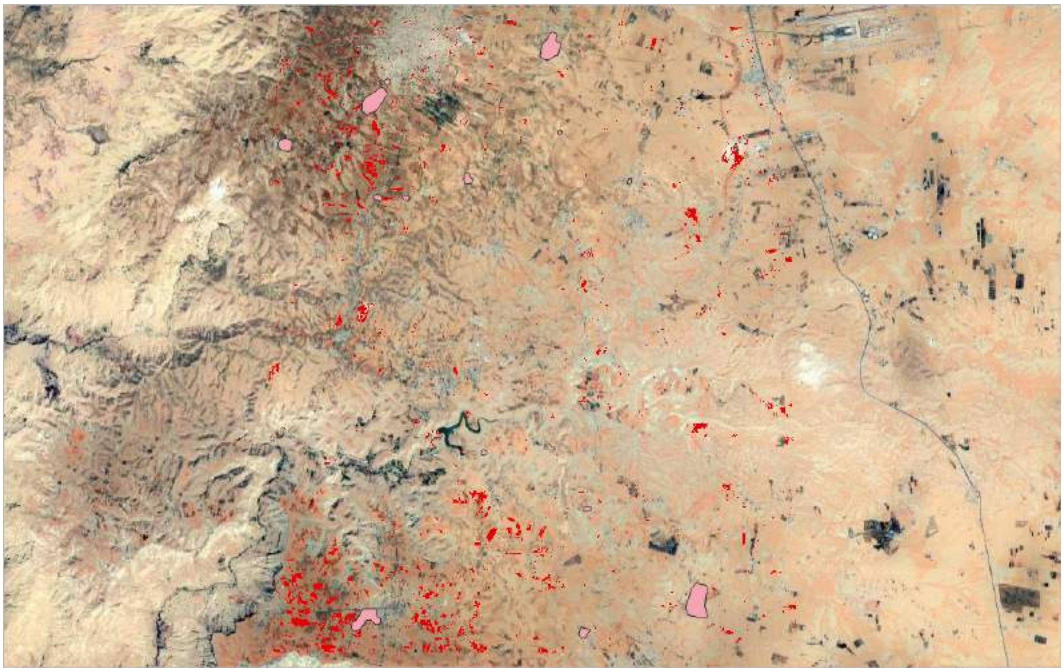
- Right-click “Detected_Change_Raster” in the Layers Panel and click “Properties”.
- In the Symbology tab change “Render type” to “Palleted/Unique Values”.
- Click the “Classify” button.



- Click the “0” entry and click the red minus button to remove it, then “Apply” and “OK”.

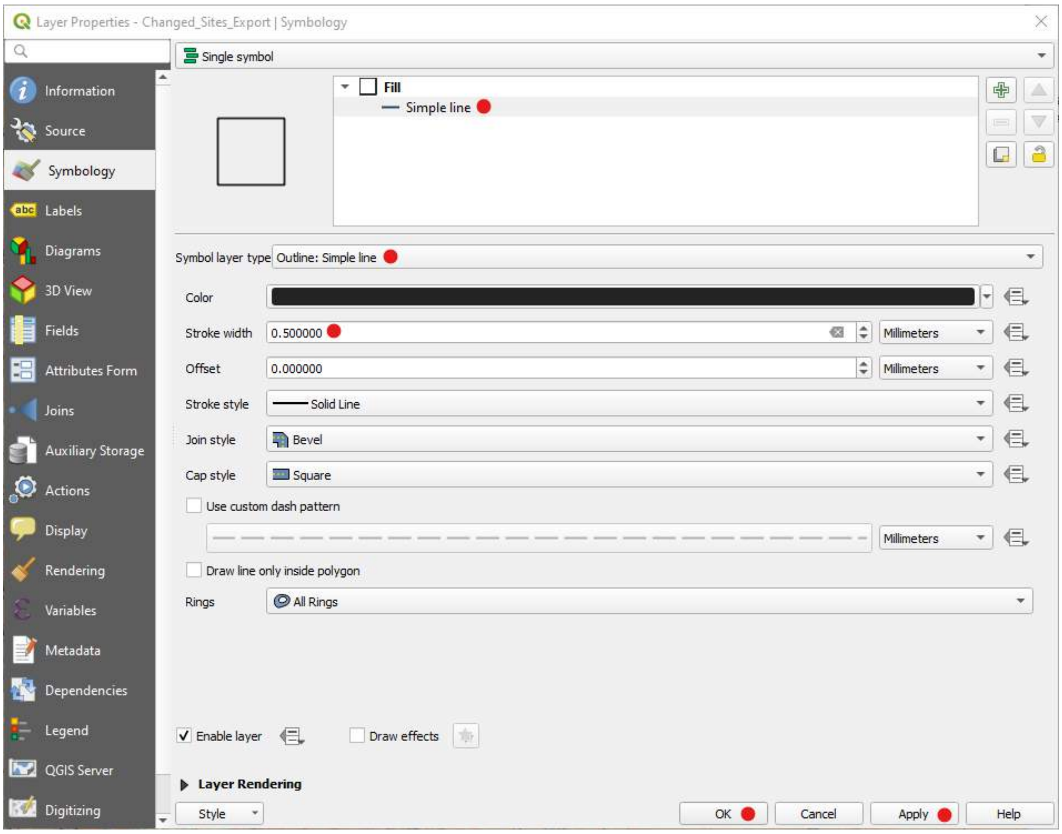


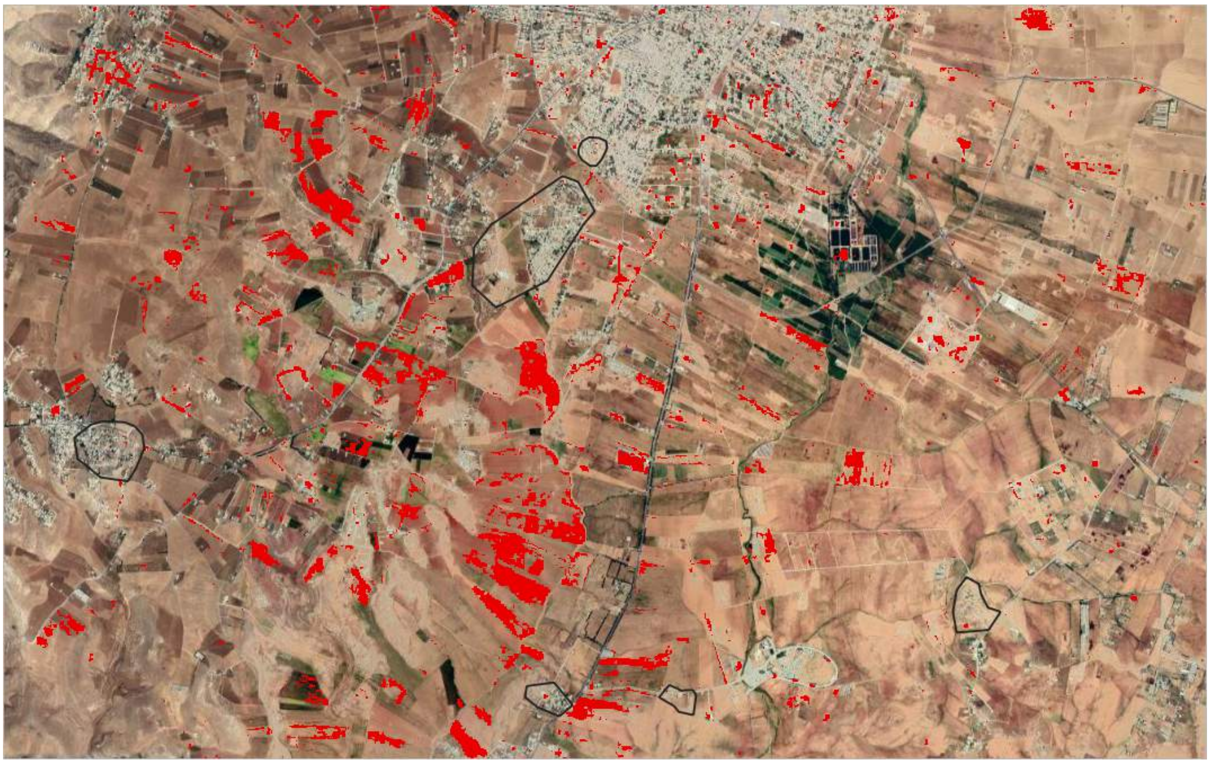
We will now be able to see the background.



However, we want to be able to see the background through the sites as well.

- Right-click the shapefile in the Layers Panel and click "Properties".
- Click "Simple fill" on the Symbology tab.
- Change "Symbol layer type" to "Outline: Simple line".
- Change "Stroke width" to 0.5, click Apply and OK.

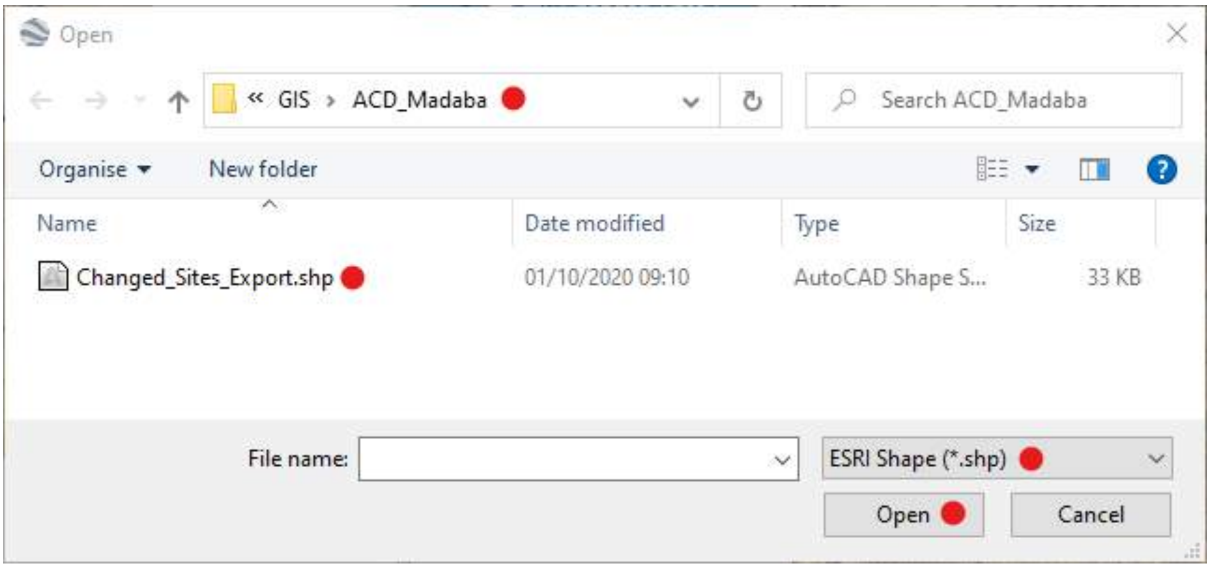




This satellite imagery that will appear in QGIS is the most recent imagery available.

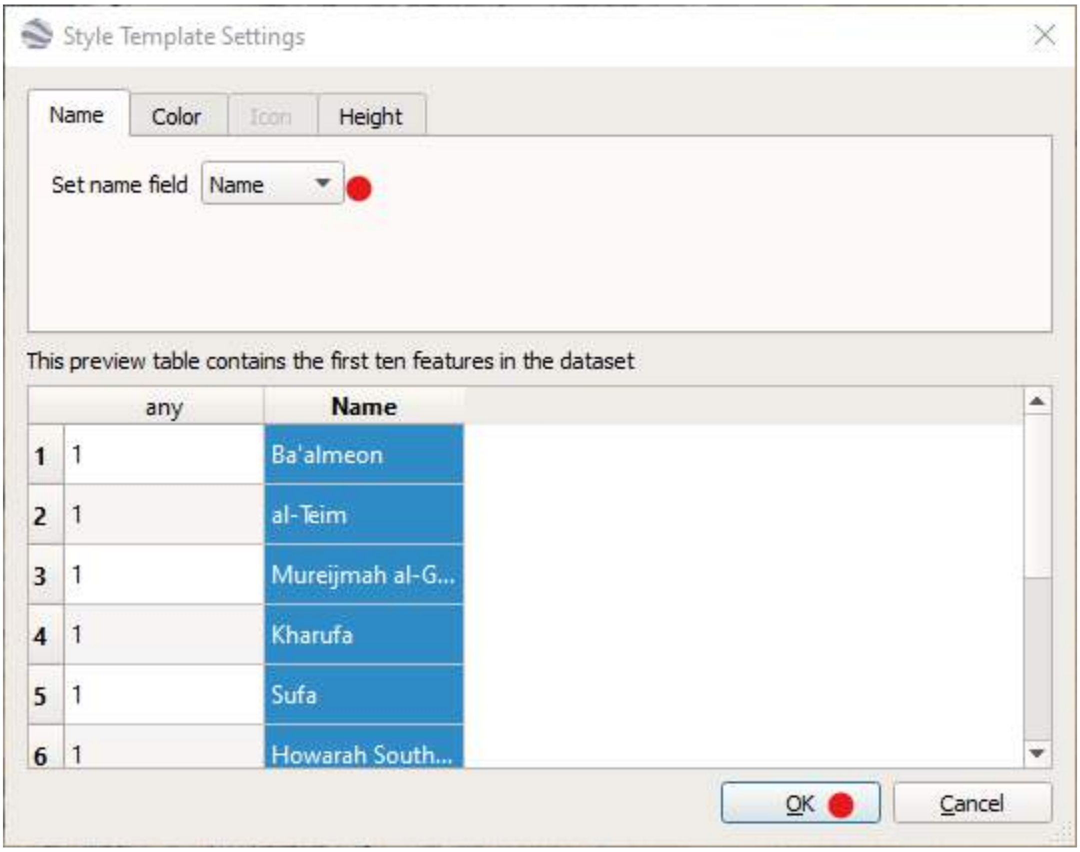
However, our analysis was for the period between the summer of 2017 and the summer of 2018. To find and check imagery in this range we need to open the sites in Google Earth Pro.

- Open Google Earth Pro.
- Click “File” > “Open”.
- Change the filetype to “ESRI Shapefile”.
- Navigate to your “ACD_Madaba” folder.
- Select “Changes_Sites_Export” and click Open.

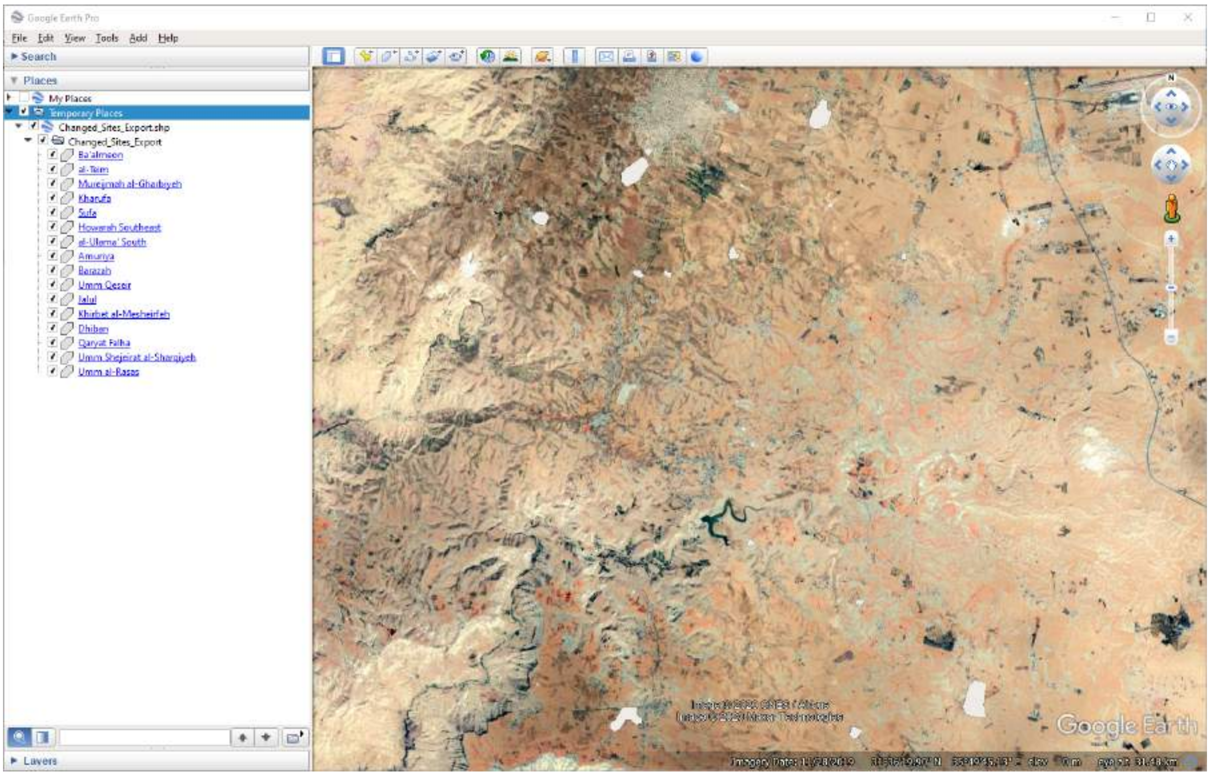


- Click "Yes" when it asks about a style template.

- Change "Set name field" to "Name" and click OK and click Save.

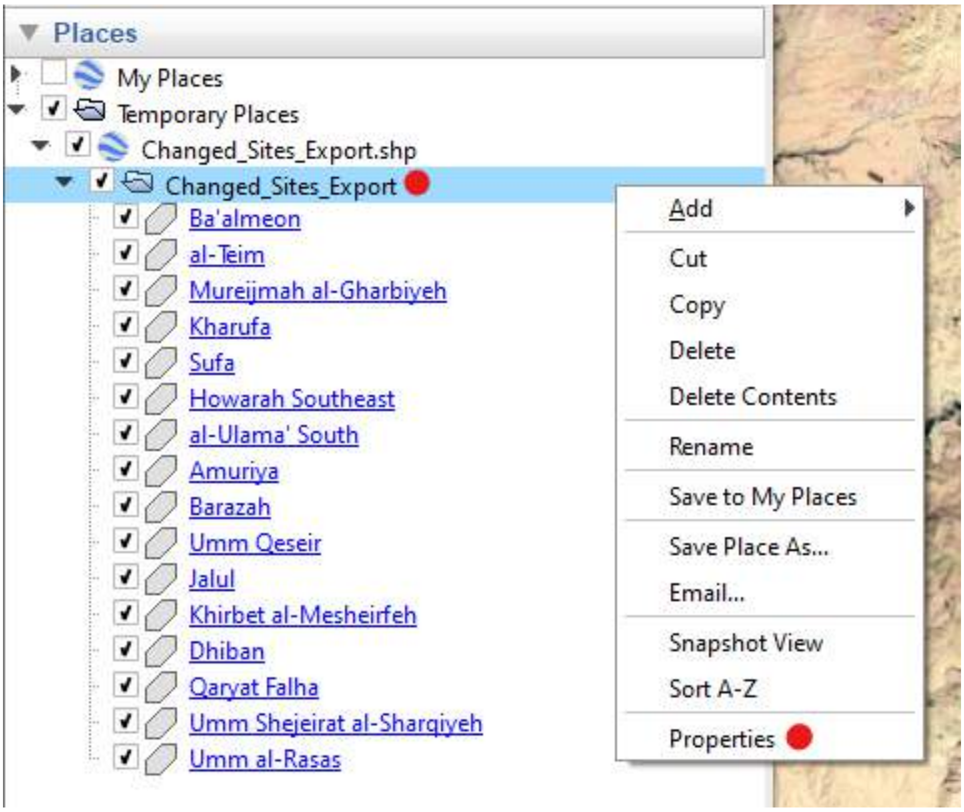


This will add the sites to "Temporary Places".

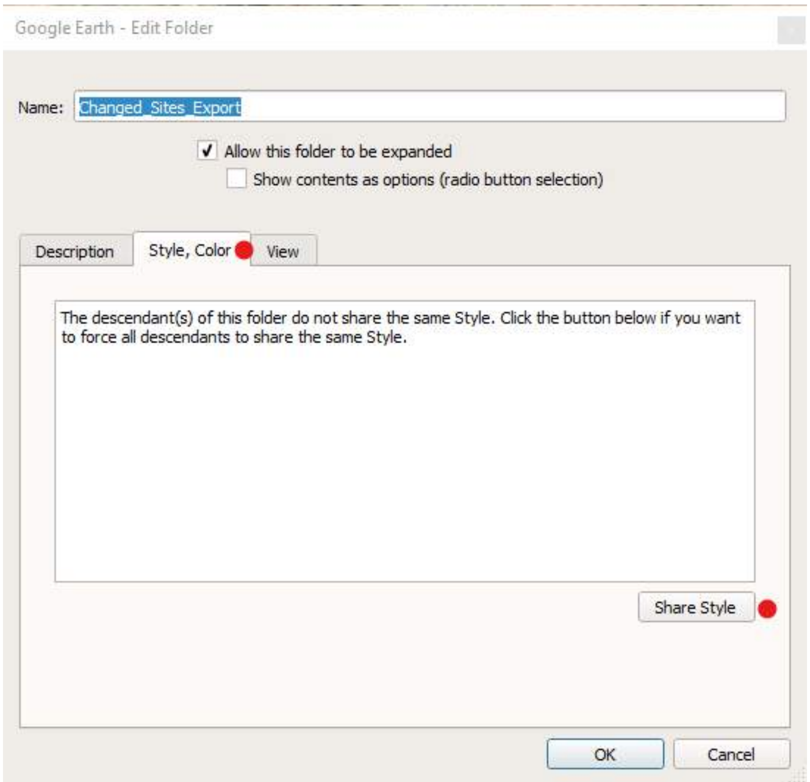


We now need to make the Google Earth imagery visible through the sites.

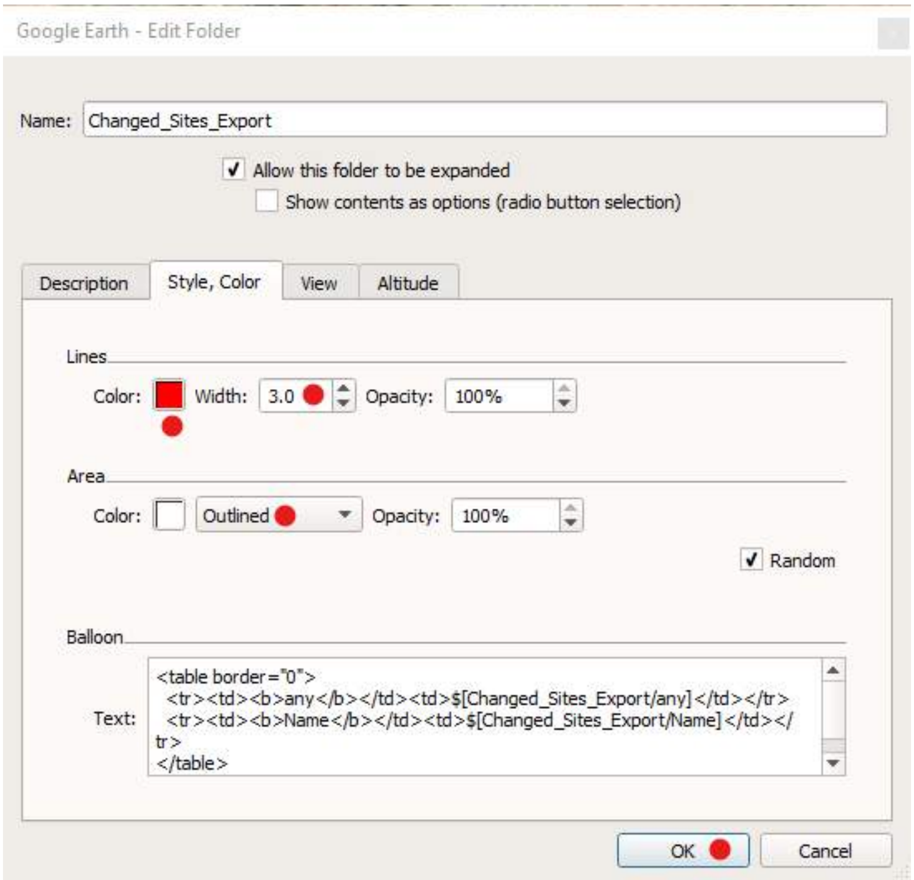
- Right-click the "Changed_Sites_Export" folder and click "Properties".



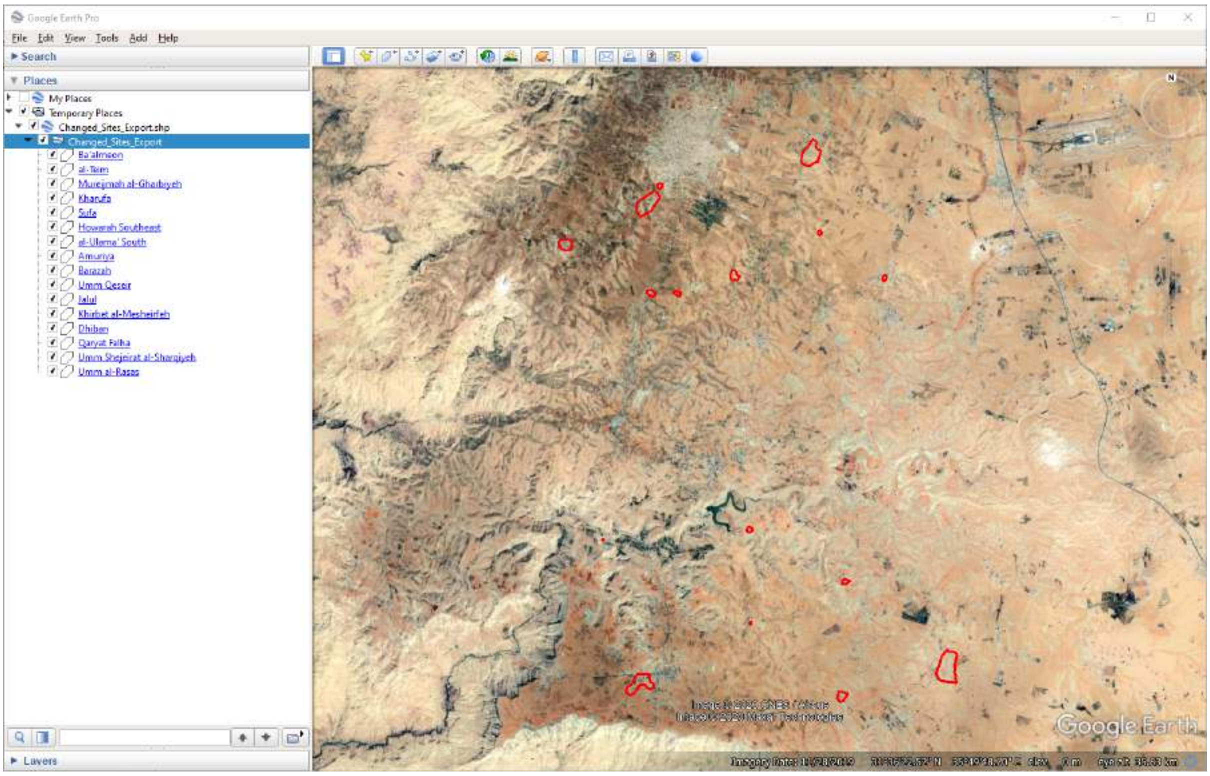
- Click the “Style, colour” tab and click “Share Style”.



- Change “Filled+Outlined” to “Outlined”, “Width” to 3.0, “Color:” to red and click OK



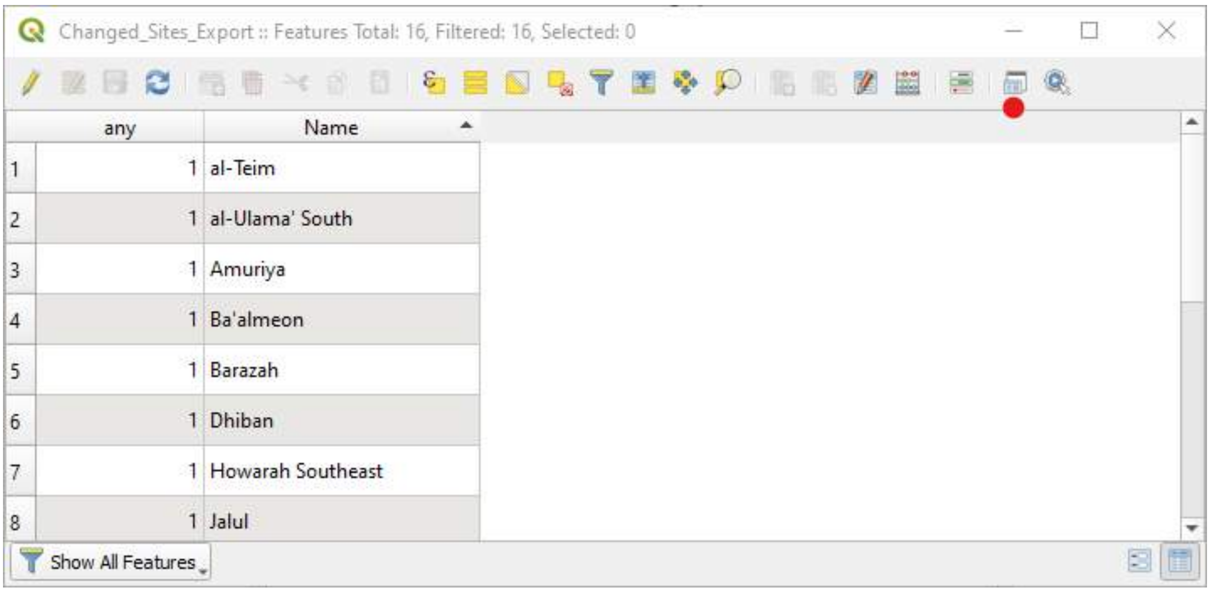
The sites will now be much easier to see.



1.4 Validating the ACD results in QGIS and Google Earth (video tutorial)

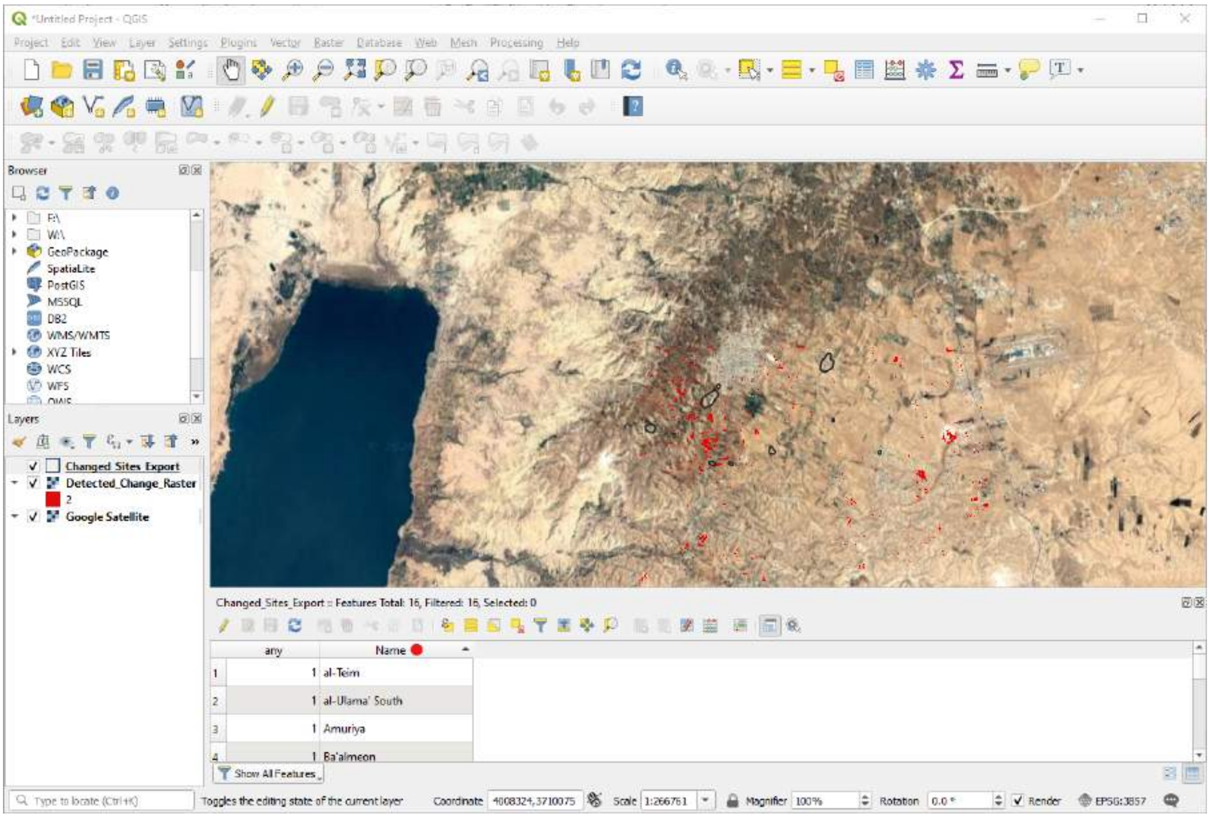
We are now going to check our results in QGIS and Google Earth to see if the changes that have been detected by the script represent disturbances to the sites visible in the imagery. This will involve switching between QGIS and Google Earth.

- Switch to QGIS, right-click the shapefile in the Layers Panel and click "Open Attribute Table".
- In the Attribute Table itself click the "Dock Attribute Table" button.

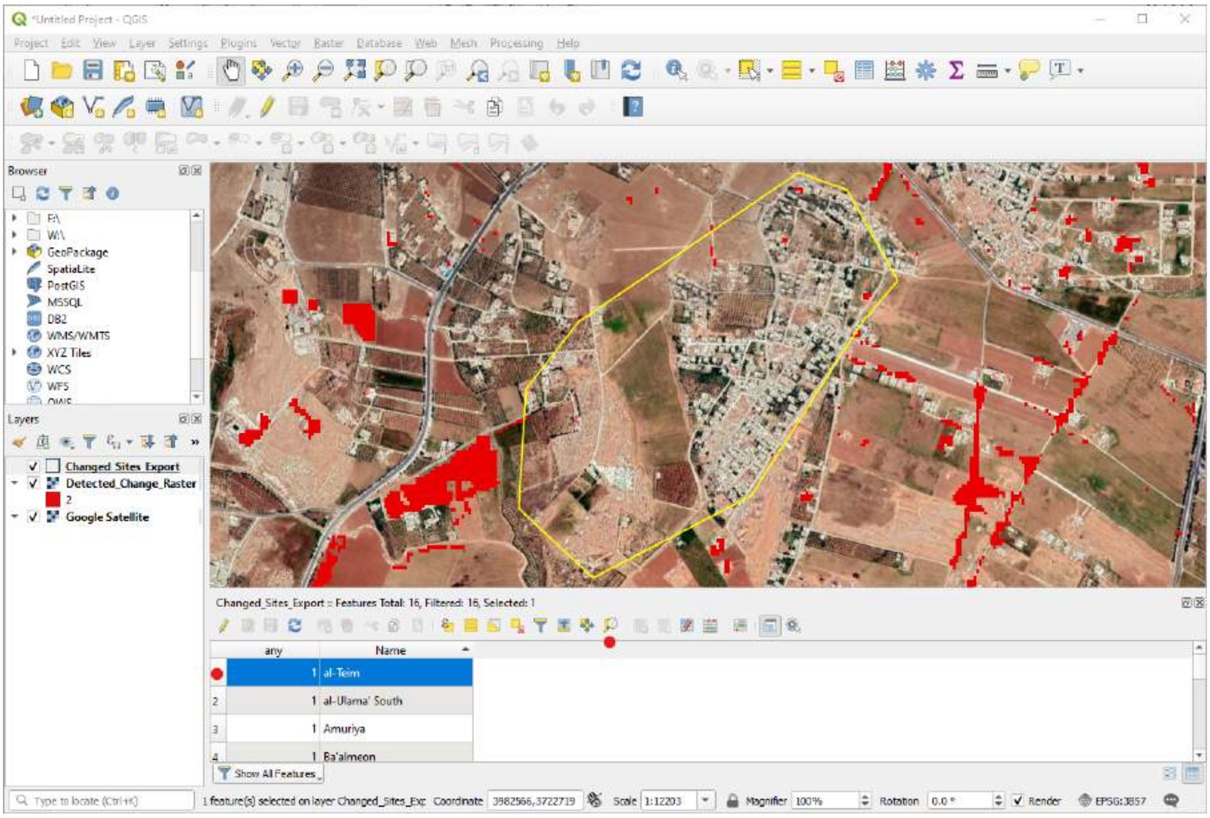


This will embed the Attribute Table in the main QGIS Window.

- Click the "Name" field to sort the sites alphabetically.

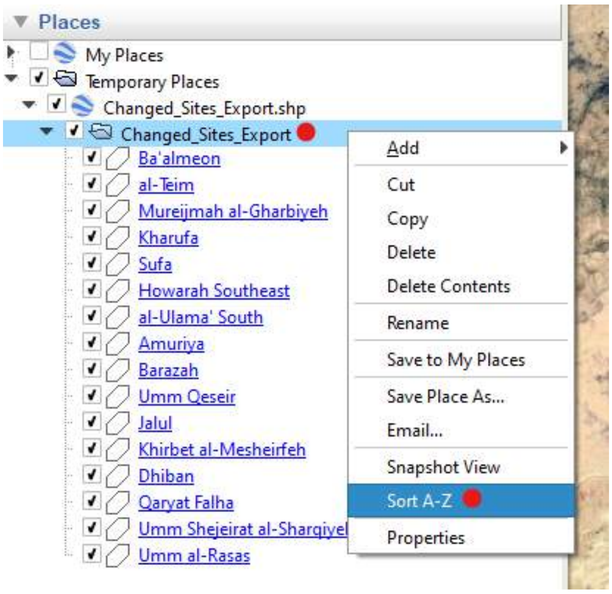


- Click on row 1 "al-Teim" and click the "Zoom to Selected" button.



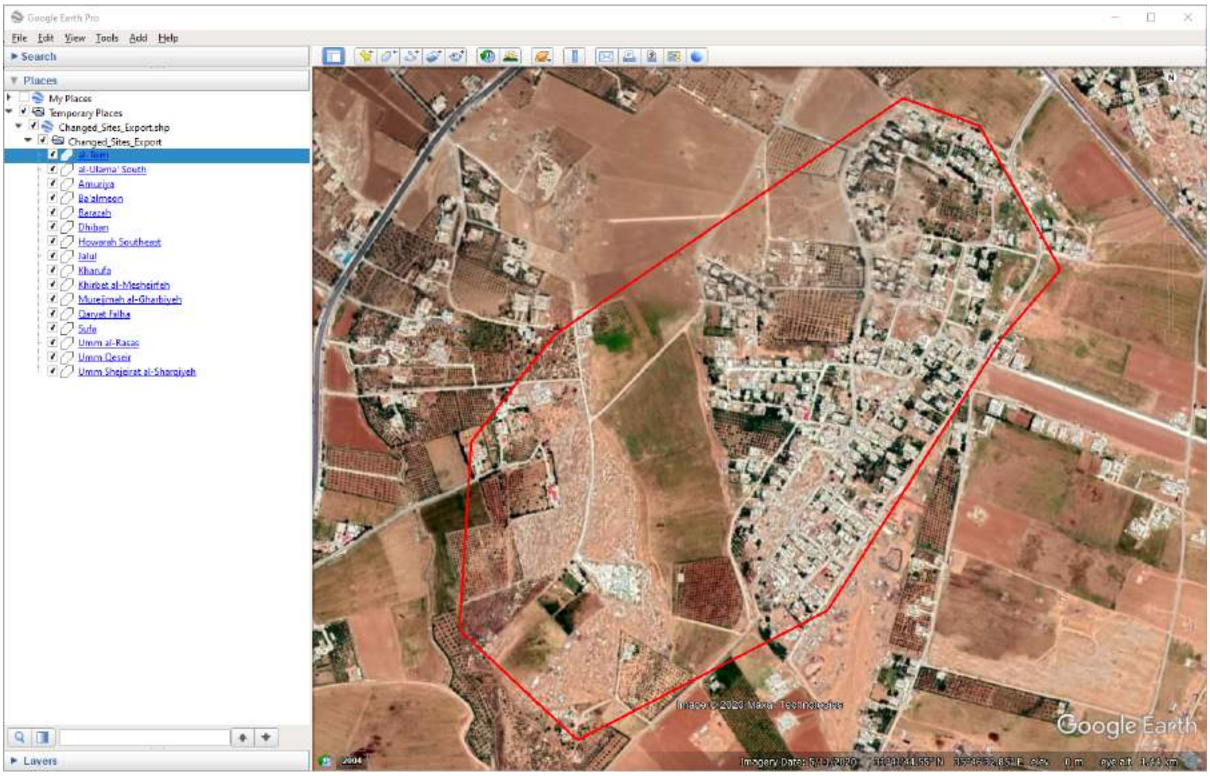
Within the site polygon, you will see the areas for which change was detected between the summers of 2017 and 2018.

- Switch to Google Earth Pro.
- Right-click the “Changed_Sites_Export” folder and click “Sort A-Z”.



- Double-click next to “al-Teim” to zoom into the site.

You will see the same site as in QGIS.



- Turn on the Time Slider and move to imagery from 12/6/2016 (this is closest we can get to the summer of 2017).

- Switch back to QGIS and find the largest area of change that was detected – it is in the north-east part of the site

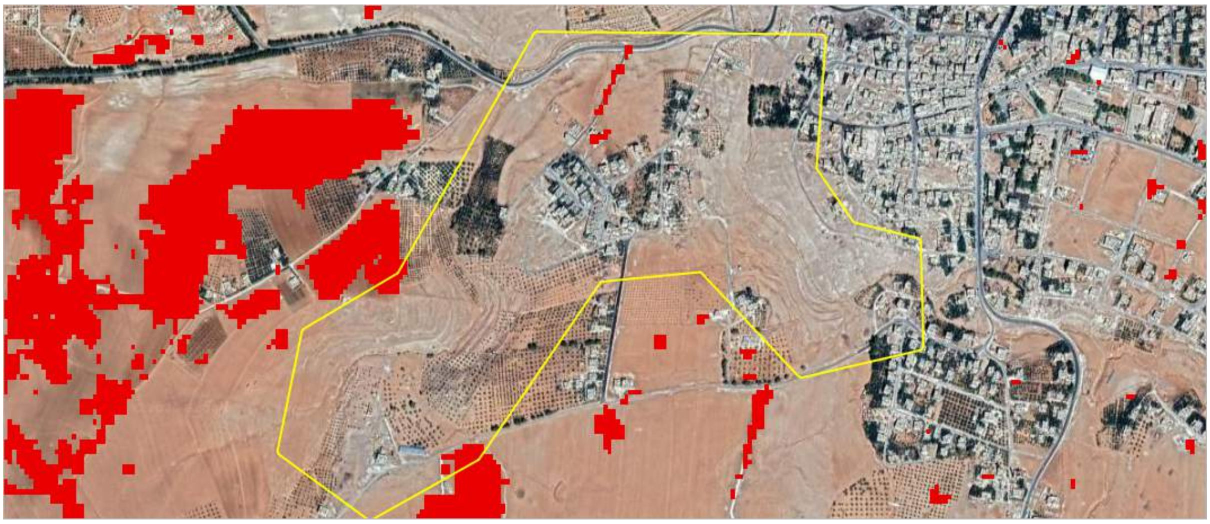
- Examine this area on Google Earth using the Time Slider.

You will notice that a house was built between December 2016 and early 2018.

If you look at other areas of change using this method, you will see that a road was also built, and a house was developed in the north-west part of the site during this period.

We will look at one more example.

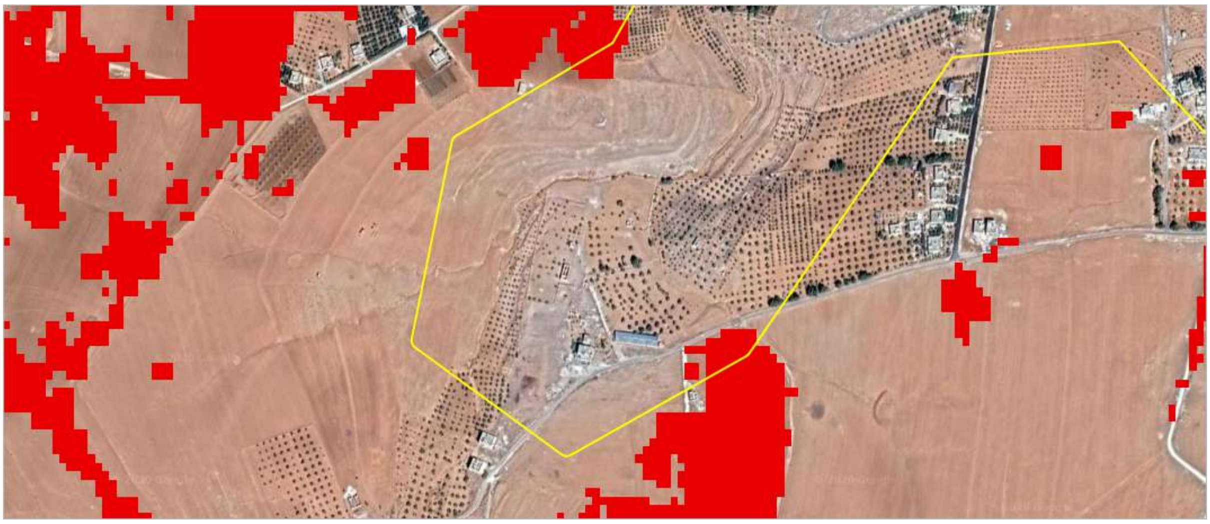
- Zoom in to Dhiban by using "Zoom to Selected" in QGIS and double-clicking in Google Earth Pro.



- Repeat the same procedure as described above for this site.

You will notice that a new road and house were built in the northern part of the site – a genuine disturbance to the site.

- However, in the south-west you will notice areas of detected change that are not disturbances. These are fields.



These are false positives – although change was detected in these areas, they are not direct disturbances to the archaeology.

It is unlikely that the imagery detected crops and no crops in the images as the script takes this into account. It is more likely that one field was either wet or freshly ploughed in one image and not the other, resulting in a significantly different spectral signature.

This is why it is vital to validate the ACD results, either using high-resolution satellite imagery or on the ground if possible.

2 ACD for site points around Jufra, Libya (video tutorial playlist)

We have already looked at one version of the script in an old farming area of Jordan using site polygons. The script can also be used for ACD with sites with point geometry rather than polygon geometry. We are going to look at an example from Jufra, Libya, in an arid area which has undergone massive agricultural expansion made possible by modern irrigation techniques.

2.1 Changes made to the ACD script (video tutorial)

First, we are going to look at the changes we have made to the script to make it work for our Jufra sites.

- Click here to open the new version of the script for Jufra : https://code.earthengine.google.com/08e103d7371abdf585e996c8e0d1972a

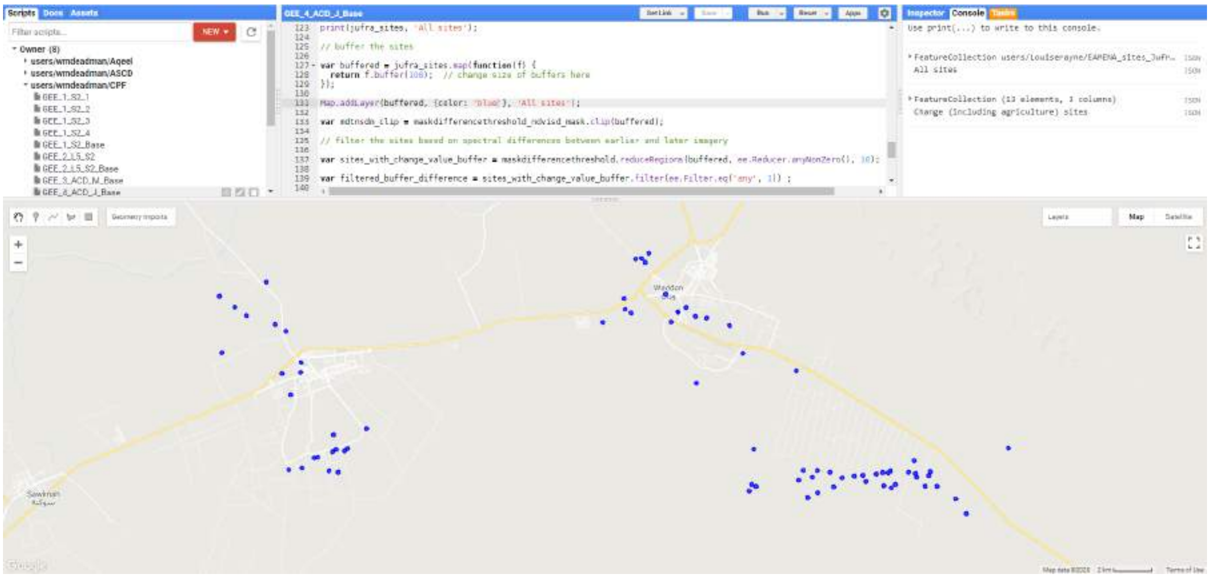
Unlike the Madaba sites, which are polygons, the Jufra sites have point geometry.

- Scroll down to line 127

```
127 var buffered = jufra_sites.map(function(f) {
128   return f.buffer(100);  // change size of buffers here
129 });
```

You will notice that to make the script more effective we create a buffer zone around the points. At the moment this is set to 100m, but we can change this if we wish to make the area around each site larger or smaller.

- Turn off all the layers in the Layers Panel and then turn on “All sites”.



You will notice that all the sites are circular and roughly the same size (with a radius of 100m).

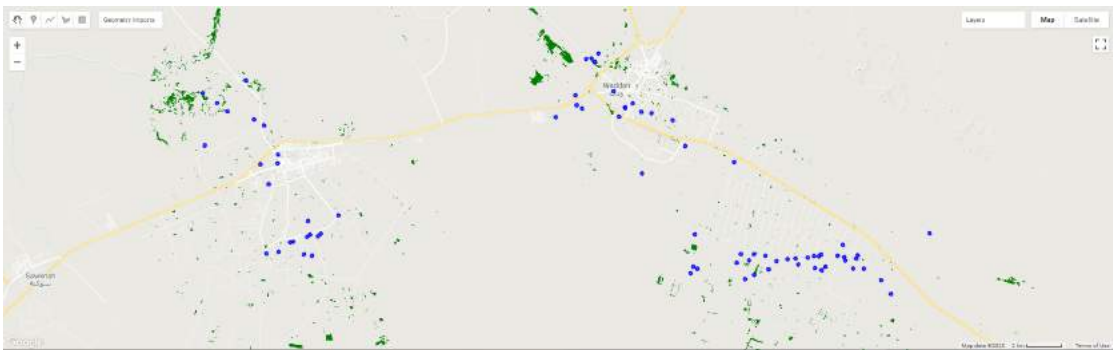
- Scroll up to line 5.

```
5   // ENTER DATE HERE: Latest date to which to apply analysis.
6   var year_later = 2020;
7   var month_later = 5;
8   var day_later = 1;
9
10  var startDate_later = ee.Date.fromYMD(year_later, month_later, day_later);
11
12  // ENTER DATE HERE: Latest date of an earlier period you want to compare it to.
13  var year_earlier = 2019;
14  var month_earlier = 5;
15  var day_earlier = 1;
16
17  var startDate_earlier = ee.Date.fromYMD(year_earlier, month_earlier, day_earlier);
18
19  // parameters for date: the date advancing function generates a time range and filters data according to this range
20
21  var delta_later = -3; //-1 will count back, 1 will count forward
22  var unit_later = 'month';
23
24  var delta_earlier = -3;
25  var unit_earlier = 'month';
```

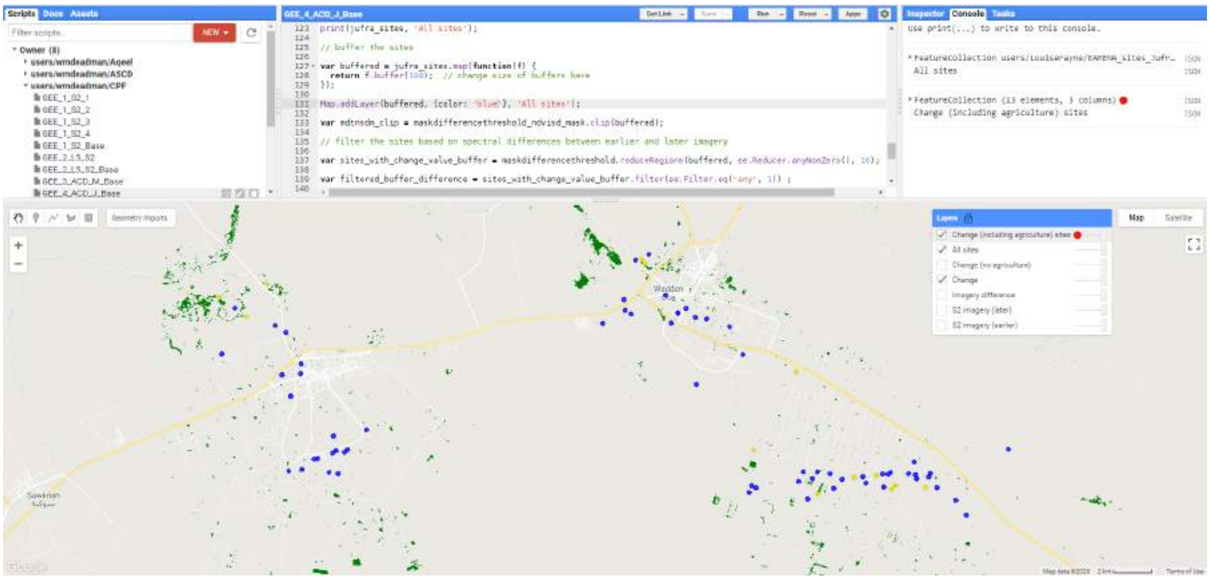
You will notice that the dates are different for this script – we are looking at the months of February to April in 2019 and 2020.

- Turn on the “Change” layer.

As new agricultural areas are a major disturbance in this part of Libya, the script is programmed to compare this “Change” layer to our sites (instead of the “Change (no agriculture)” layer like in the Madaba example).

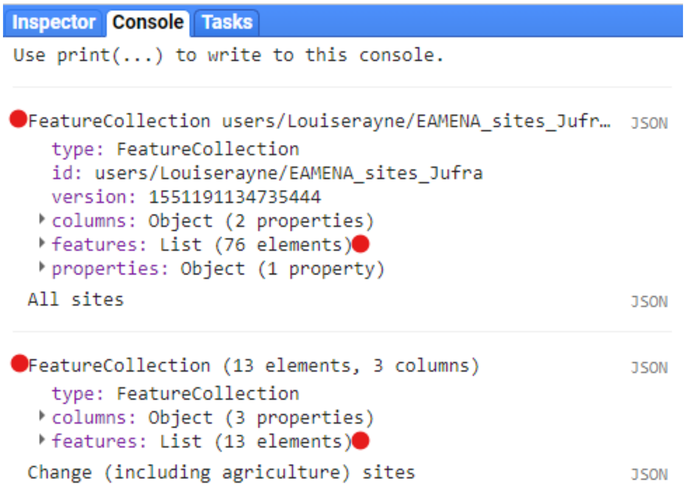


- Turn on the “Change (including agriculture) sites” layer.



- Expand the two “Feature Collections” in the Console Window

You will see that change was automatically detected at 13 sites in this layer out of a total of 76.

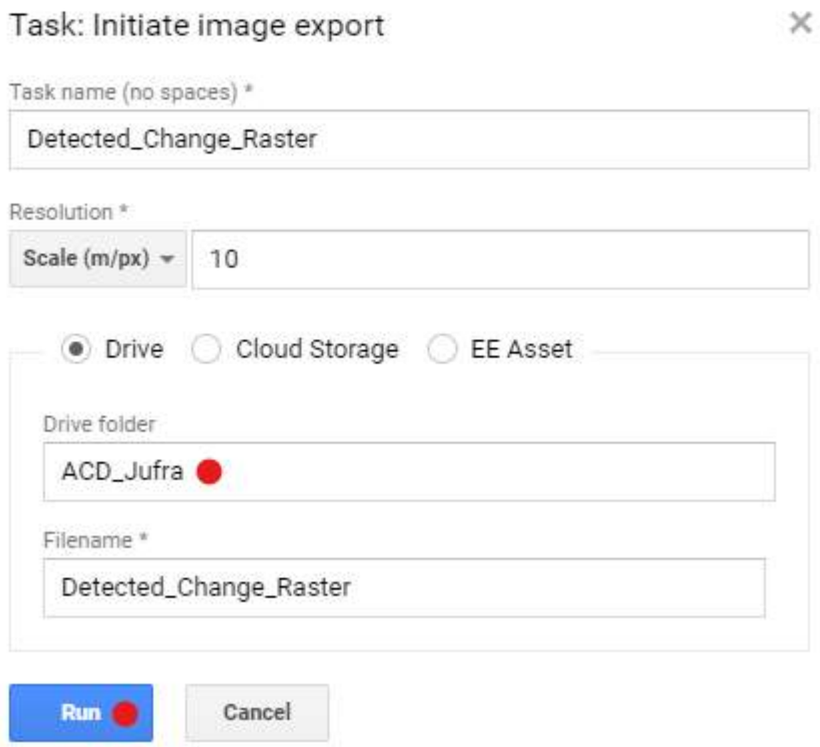


2.2 Exporting and validating the Jufra ACD (video tutorial)

We are going to follow exactly the same methodology as before to validate the Jufra results.

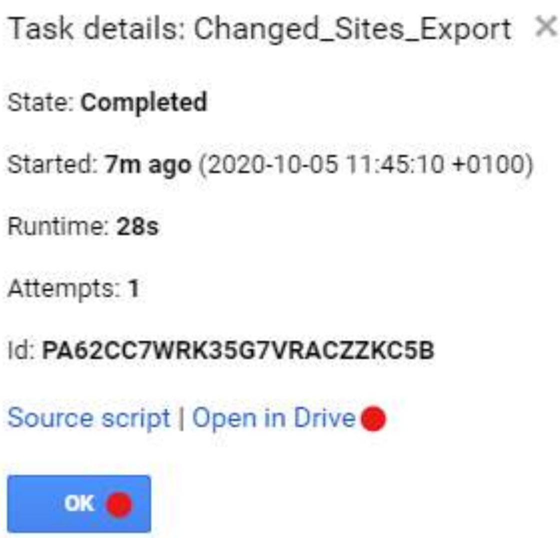
- Click on the Tasks Window.
- Click the “Run” button next to “Detected Change Raster”.

- Type “ACD_Jufra” into the “Drive folder” field and click “Run”.

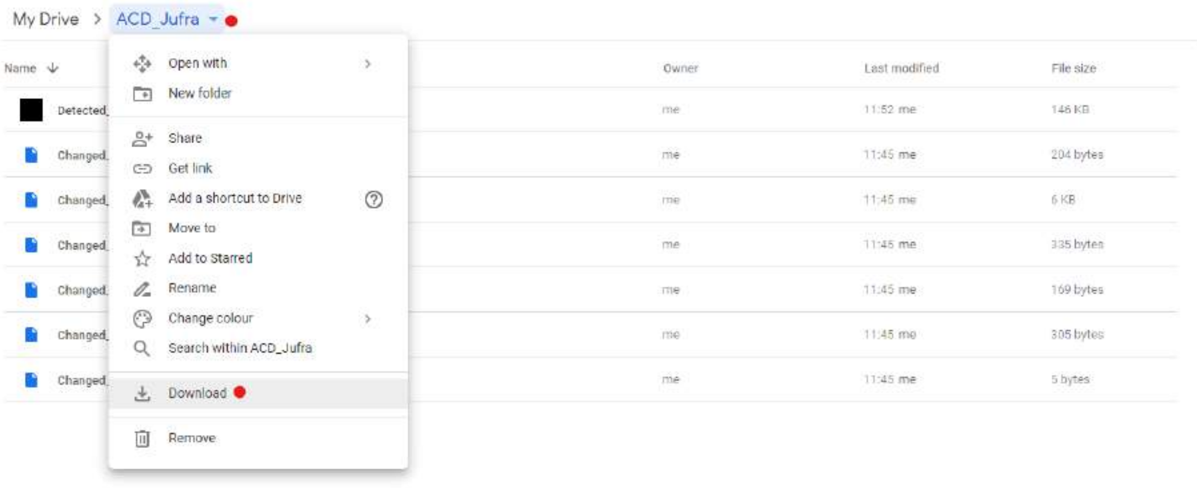


- Repeat for “Changed_Sites_Export”.
- When both have finished exporting click the “?” button that appears when you hover over the “Changed_Sites_Export” blue box.

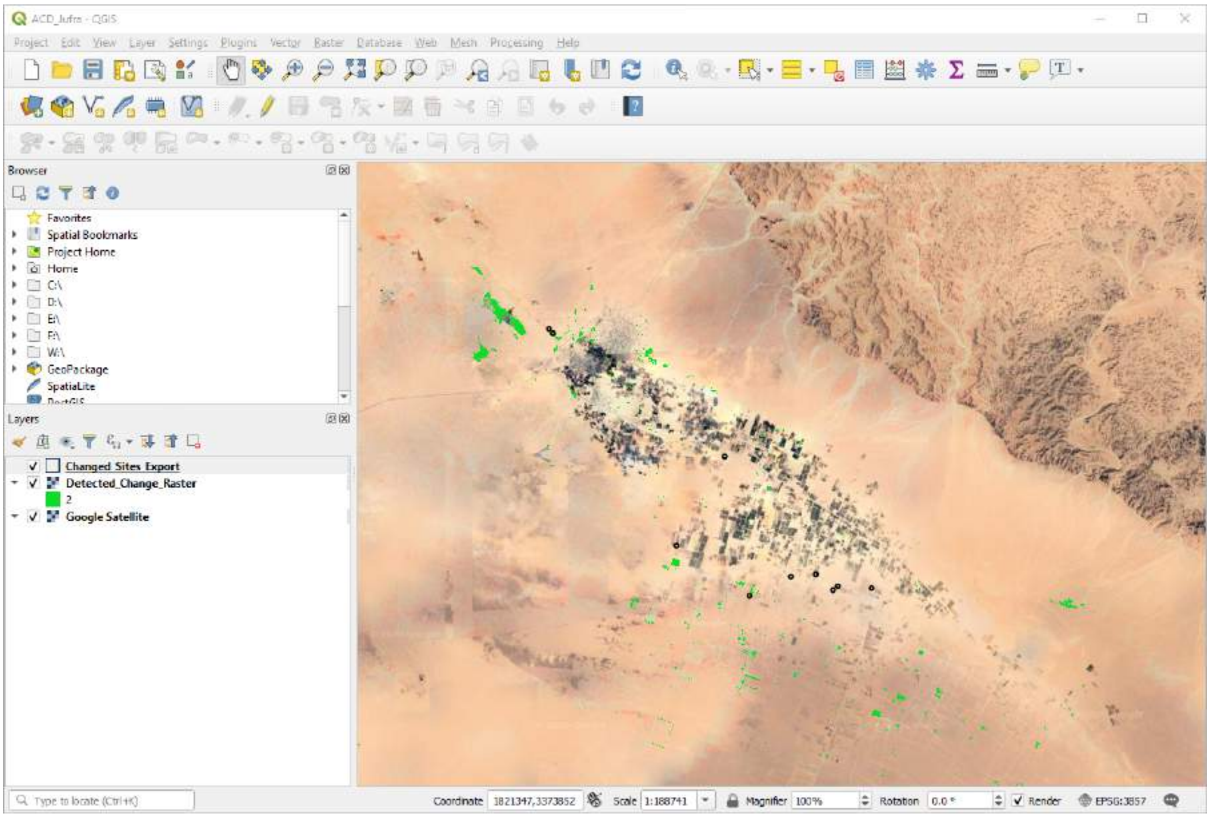
- Click “Open in Drive”.



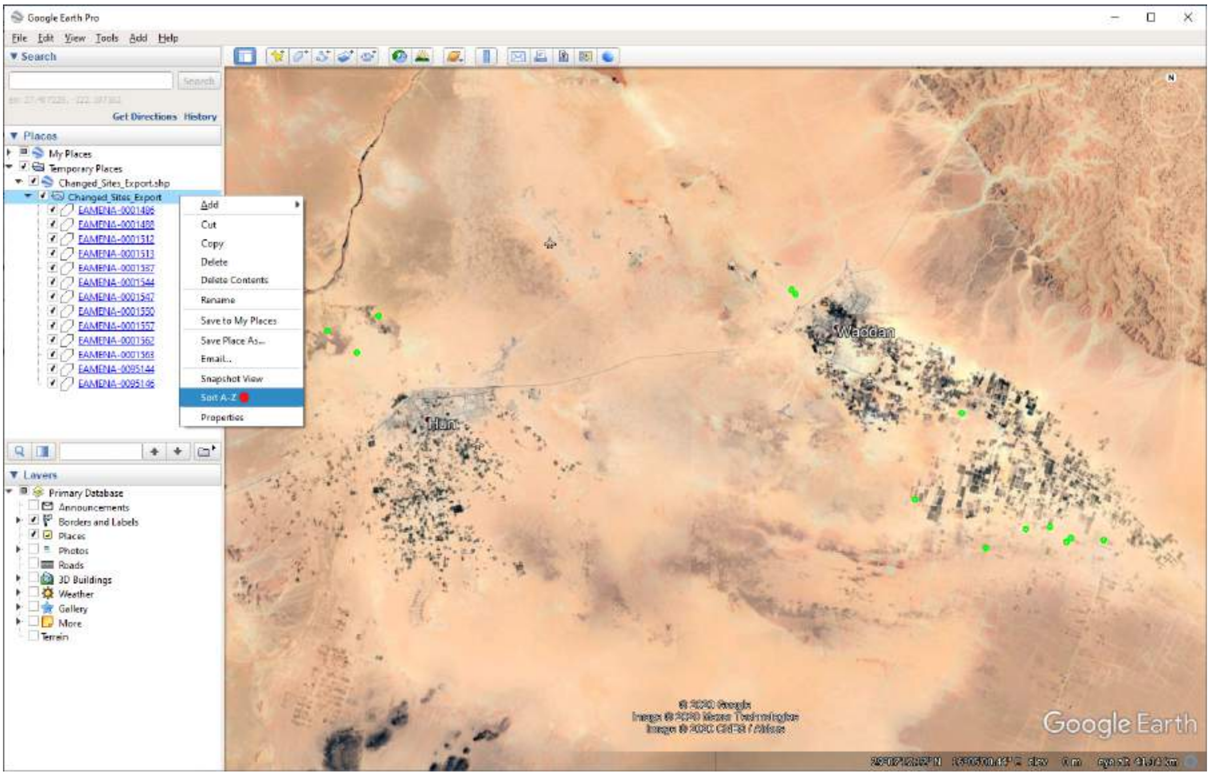
- Click the small arrow next to the “ACD_Jufra” folder and click “Download”.



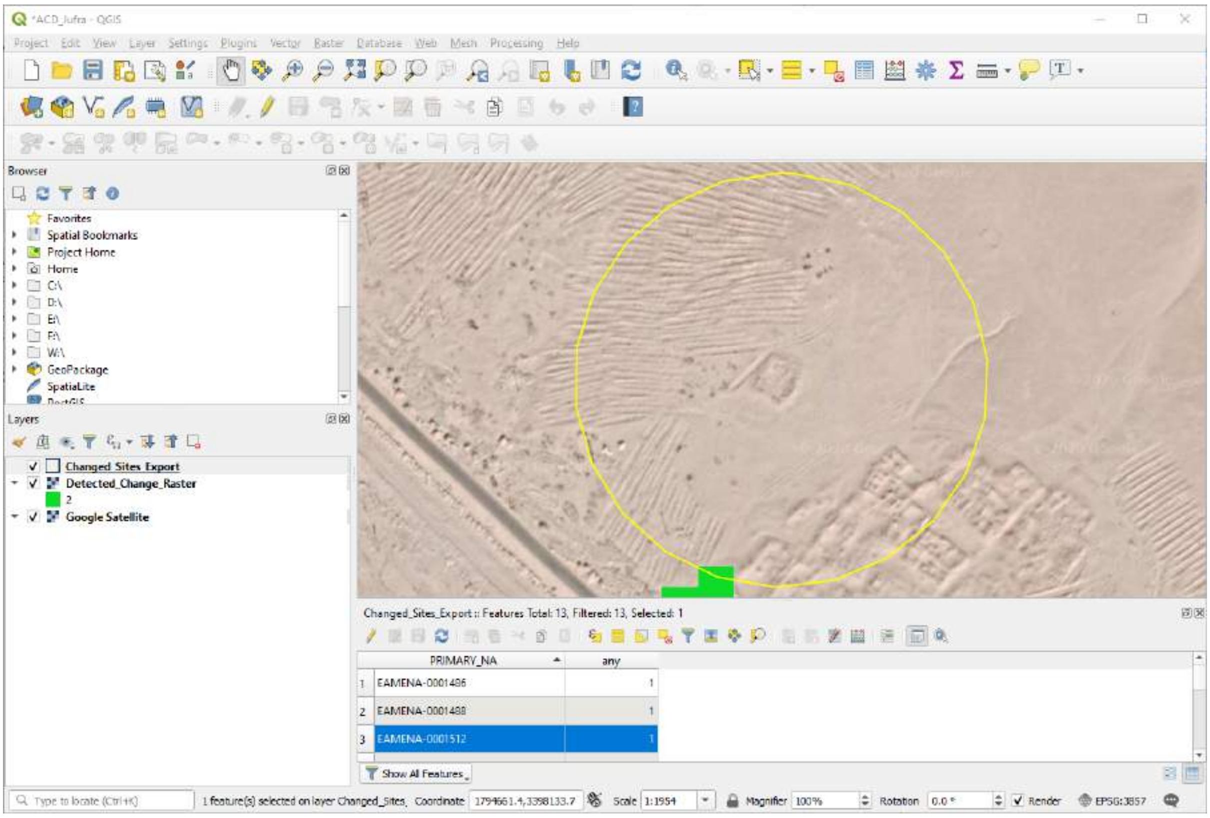
- When complete, move this zip file from your Downloads folder to your GIS folder.
- Right-click the zip file and click “7-Zip” > “Extract Here” (or use any other unarchiving software you have).
- Open the new “ACD_Jufra” folder and make sure your shapefile and raster are there.
- Add these files and a satellite imagery XYZ tiles basemap to a QGIS map.
- Alter the symbology so that the imagery can be seen through the “Change” raster and the sites shapefile.



- Open the shapefile in Google Earth Pro.
- Set EAMENA-ID “PRIMARY_NA” field as the name field.
- Change the symbology so that the background imagery can be viewed.
- Sort the sites alphabetically within the Google Earth folder.



- Open and dock the Attribute Table in QGIS, sort the sites alphabetically and zoom to site “EAMENA-1512”.



- Switch to Google Earth Pro and double-click on this site.
- Turn on the Time Slider and find imagery from Spring 2019.

In the March and April images from 2019 you will see a pool of water to the south of the site – a possible flooding disturbance that luckily is right at the edge of the buffer boundaries.

- Zoom to "EAMENA-1547" on QGIS and Google Earth Pro.
- Compare the Spring 2019 and 2020 imagery.

You will see that the old irrigation system has been almost completed destroyed.

ACTIVITY: validate the results of the ACD script for the Madaba and Jufra datasets, identifying the disturbances that have occurred to archaeological sites that have been detected in Google Earth Engine.