Welcome to Geo-informatics for Agriculture

This course introduces you to Geographic Information Systems (GIS) using QGIS.

Description

Strategic and operational management of national agriculture requires several spatial datasets. Integration of the varied datasets in a spatial database permits easy data management and analysis to support decision making. Geographic Information System (GIS) software provides a framework to support spatial data collection, management and analysis. This training manual introduces theoretical concepts and practical activities that reinforce understanding of agricultural spatial data management and analysis.

Topics

The course will introduce the following topics:

- Introduction to GIS
- Capturing and creating data
- Geographic and projected coordinate systems
- Spatial databases
- Spatial analysis and visualization

Software requirements

- Windows 10 or 11 environment.
- QGIS 3.28 LTR 'Firenze' available at this link https://qgis.org/en/site/forusers/download.html
- Datasets for the course are available for download on each topic page.

Useful geo-data sources

Dominica's public Geographic Information System (GIS) repository

The Humanitarian Data Exchange

ArcGIS Hub

Esri Land Cover

Feedback

Use this form to get assistance with GIS matters.

On this page:

Introduction to GIS

Geographic Information Systems (GIS) refers to the technology used for the effective collection, storage, retrieval, processing and display of geospatial data. These data may include:

- topographic data relating to physical characteristics of the earth, e.g. streams and mountains, roads, etc.
- political data, e.g. administrative boundaries
- land use data, e.g. farm lands and crops, housing, etc.

and several others. Geospatial data have coordinates such as latitude and longitude which allow spatial features to be located on the earth.

The technology includes hardware devices and supporting software applications which are used throughout the data cycle. Satellites, drones, field sensors, GPS devices, mobile phones, computers, spatial databases and GIS applications all fit into GIS. As an example, you may consider using a soil moisture sensor to collect data from a farm and then transfer it automatically over the internet to be stored in a database which would later be analysed by a user, using a GIS desktop application.

GIS applications

There are several desktop applications, supporting tools and web-based applications. Some well-known applications are:

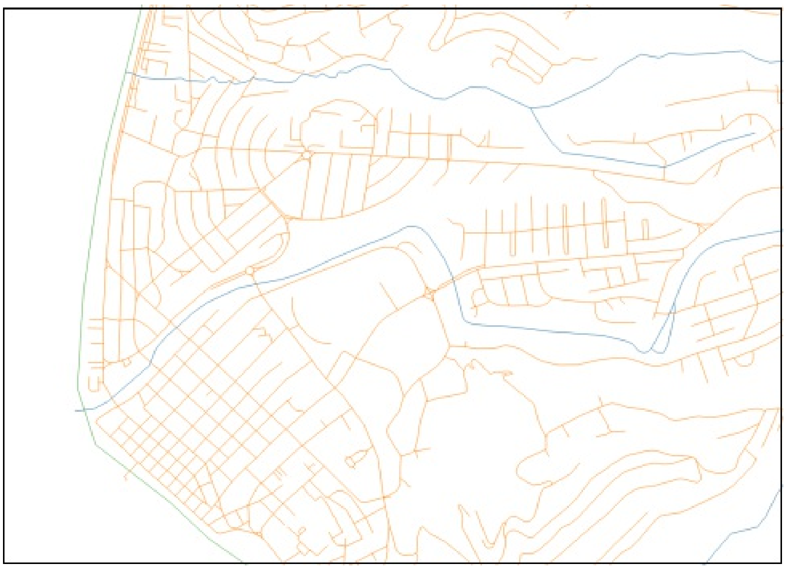
- QGIS
- ArcGIS
- Google Earth

GIS data

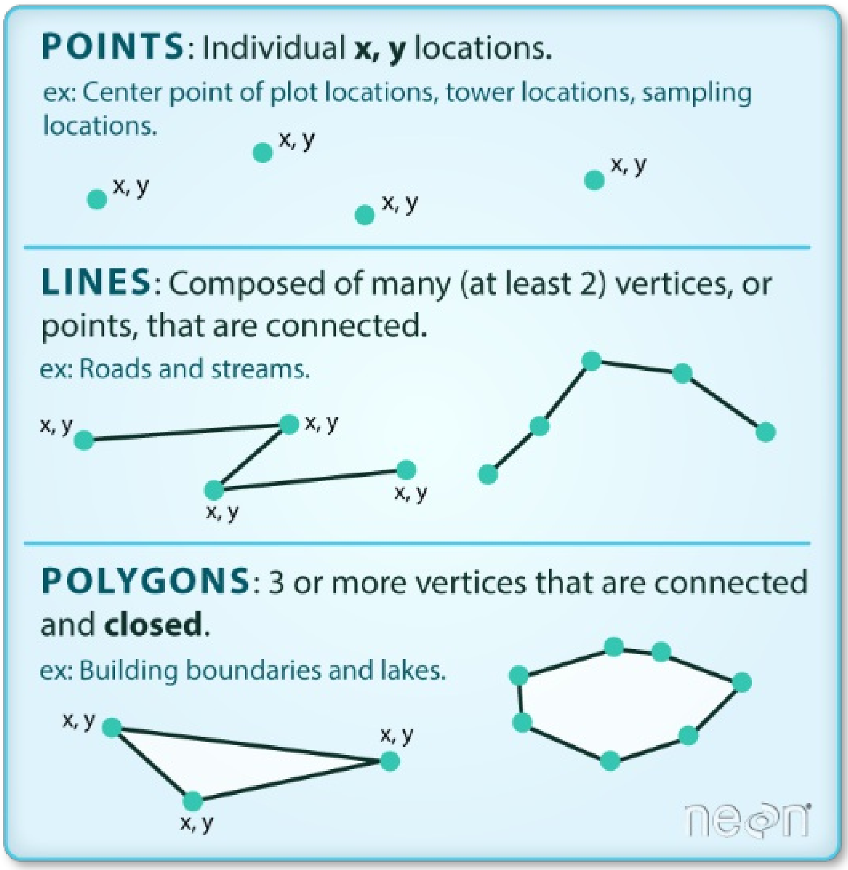
GIS data fall into two categories:

1. Vector data
2. Raster data

Vector data

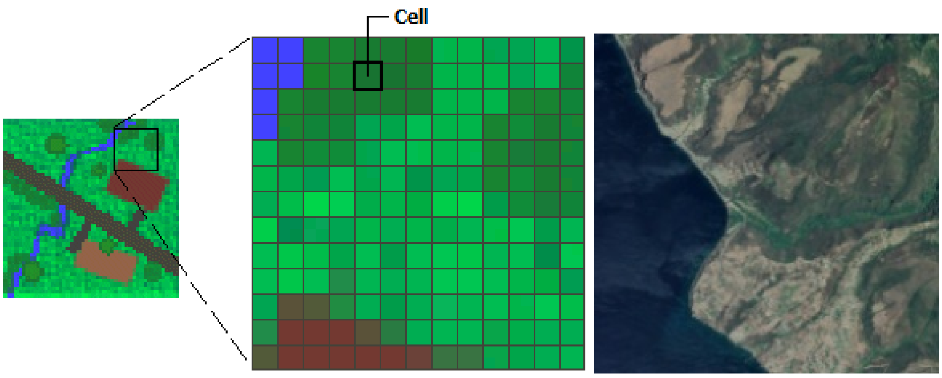


In the vector model, features on the ground are represented as either points, lines or polygons.



Credit: earthdatascience.org

Raster data



The raster model uses a grid of cells where each cell represents an attribute of a feature. Think of an image which is made up of cells called pixels. A point can be represented as a pixel, while lines and polygons would be sets of adjacent pixels. Scanned maps and satellite images are examples of raster data.

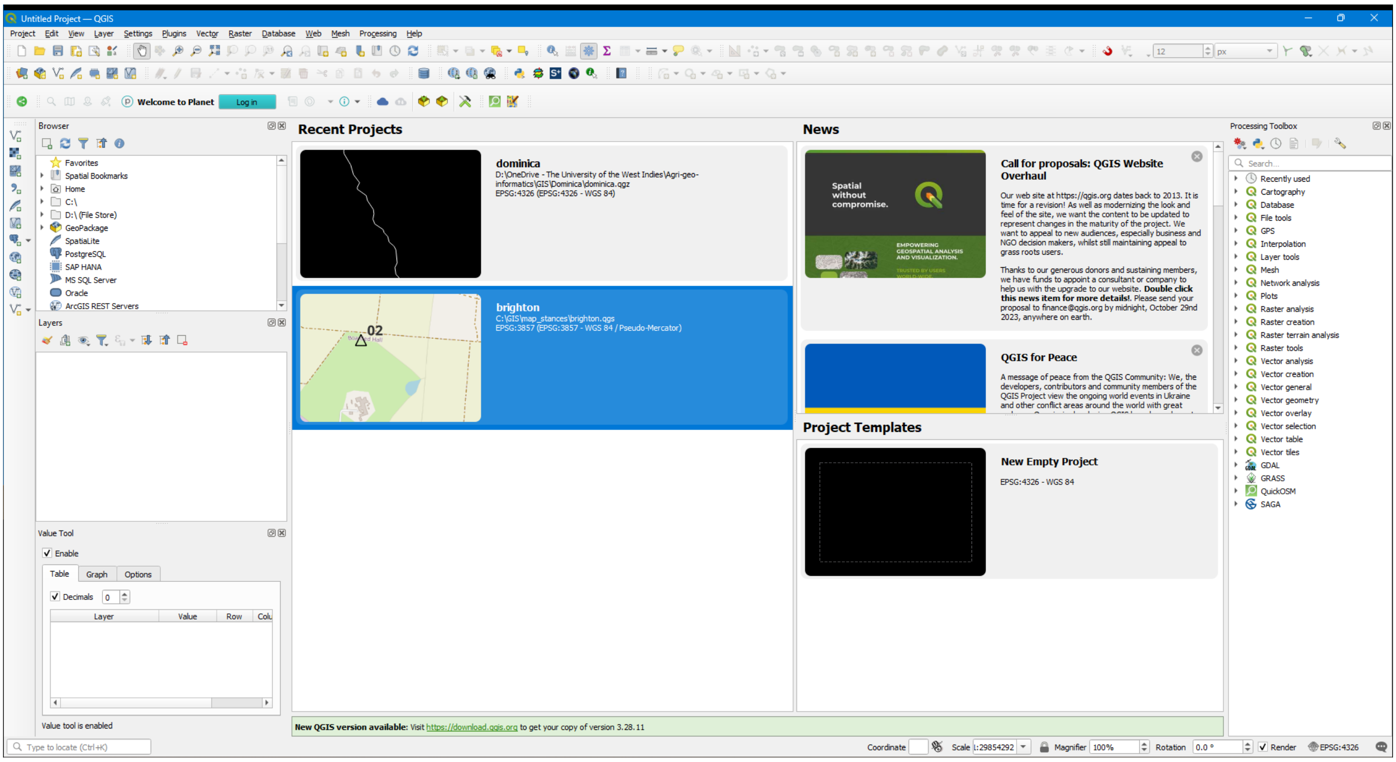
On this page:

Introduction to QGIS

QGIS is one of many Geographic Information Systems (GIS) applications. It is an opensource software that is free to use and has several plugins to improve functionality.

- Launch the QGIS application by opening **QGIS Desktop 3.28.xx** from the Windows Start Menu.

The main interface will be similar to the one below, with the menu bar, toolbars and panels. The panels and toolbars can be dragged around the interface or docked to the sides.



Panels and Toolbars

Panels and toolbars allow easy access to functions and tools. They can be activated or deactivated from the menu bar or by right-clicking any toolbar. We will add a few useful toolbars. On the menu bar, go to `View --> Toolbars` and select the following toolbars:

- Data Source Manager Toolbar
- Digitizing Toolbar
- Manage Layers Toolbar
- Snapping Toolbar

You can go to `View --> Panels` or right-click any toolbar to add these panels:

- Browser Panel
- Identify Results Panel
- Layers Panel

Creating/Saving a project

- On the menu bar, go to `Project --> Save` or use the save icon on the `Project Toolbar`.
- Navigate to a preferred folder and create a new folder called `Dominica-training`.
- Save the project as `dominica.qgz`.

Adding vector data

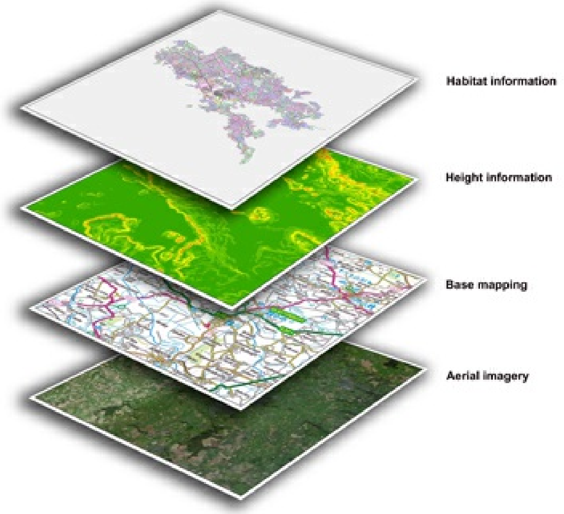
- Download the following file to the project folder:

Dominica administrative boundaries - country outline and parish boundaries.

- Drag the file into the Layers Panel.
- Click `Add Layers` in the popup window.
- Alternatively, you can go to `Layer --> Add Layer --> Vector Layer`. You can also use the `Manage Layers Toolbar`.
- Under source, press the overflow icon (3 dots) to browse for the vector file.
- Click `Add`, click `Close`.

The files will appear in the Layers Panel.

About layers



In a GIS application, data are managed in layers stacked on each other, e.g. farmlands over the admin boundaries stacked on top of a basemap. The order of the layers will influence their visibility. The layers can be reordered by dragging them up and down in the `Layers Panel`.

- Reorder the layers so that `parishes.shp` is above `coastline.shp`.

The zip file contain several files. Notice that the `Layers Panel` displays the shape files (.shp) as a group.

- Expand or collapse the group by clicking the arrow on the left.
- Use the `Manage Map Themes` icon (eyeball) on the Layers Panel to `Hide All Layers`.
- We will select the shapefiles. Check the boxes next to `parishes.shp` and `coastline.shp` layers.
- If the layer is out of focus in the view pane, right-click the layer and choose `Zoom to Layer(s)`.
- You can remove layers from the `Layers Panel` by selecting them and clicking the `Remove Layers/Group` icon. (Use CTRL + click to select

multiple layers).

Vector file types

Vector files come in several formats including the popular Shapefile (.shp, .dbf, .shx), .geojson, Google KML (.kml, .kmz), etc.

Styling vector layers

There are several styles that can be applied to layers to enhance visibility. We will change the symbology of each layer to our preference.

- Double-click the `coastline.shp` layer to launch the layer properties window. Alternatively, right-click the layer and choose `Properties`.
- Select the `Symbology` tab.
- Change the `Simple Fill` to `Outline: Simple Line` and change the color.
- Click `Apply`. When done click `OK`.
- Save the project.

Attribute table

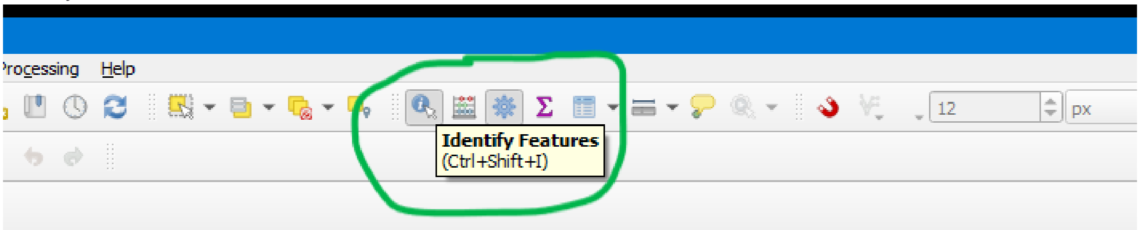
The attribute table displays the data in the vector file.

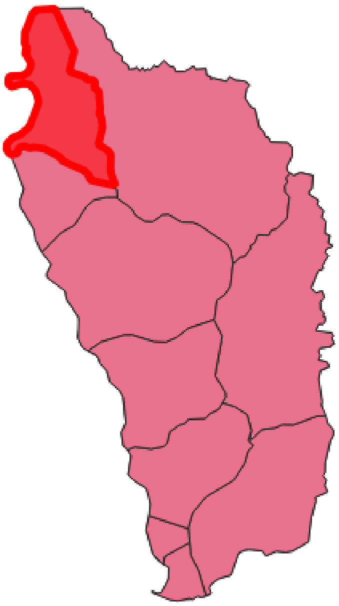
- To open the attribute table, right-click the `parishes.shp` layer and select `Open Attribute Table`.

Notice that each feature is identified by a unique ID which is essential for any data storage application. From here you can see information for each boundary, including the parish names.

- Click the right-most icon to dock the attribute table.

Identify features tool





The `Identify Features Tool` on the `Attribute Toolbar` will show data in the `Identify Results` panel for any selected feature.

- Click the `Identify Features Tool` to enable it.
- Click any parish to see the data in the `Identify Results` panel.

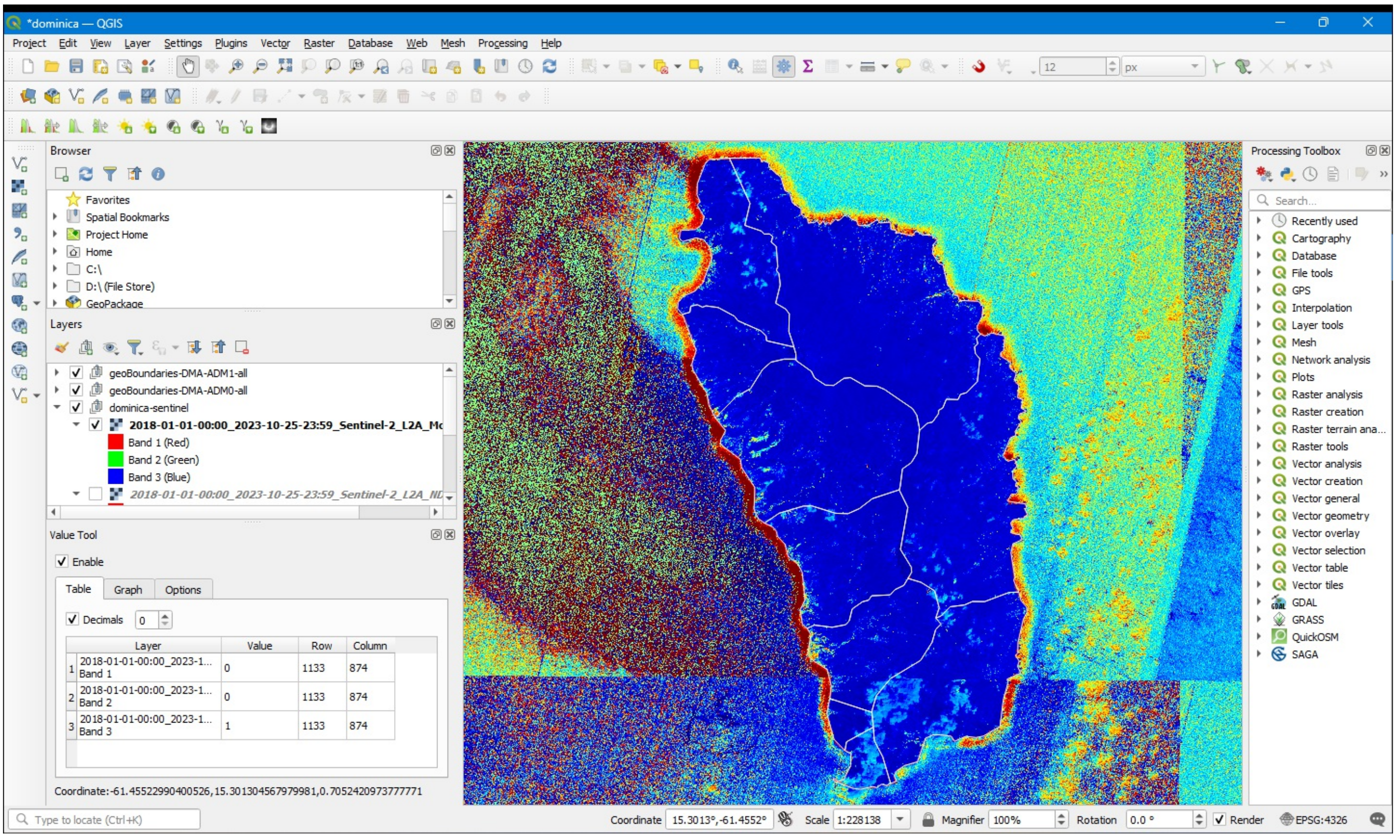
Adding raster data

- Download the following file to your project folder:

[Sentinel moisture index image]

- Use the `Browser Panel` to locate the downloaded file `moisture-index.tiff`.

- Drag the file from the `Browser Panel` to the `Layers Panel`. Alternatively, you can go to `Layer --> Add Layer --> Raster Layer`. You can also use the `Manage Layers Toolbar`.
- Arrange the layers so that `moisture-index` is at the bottom.
- Save the project.



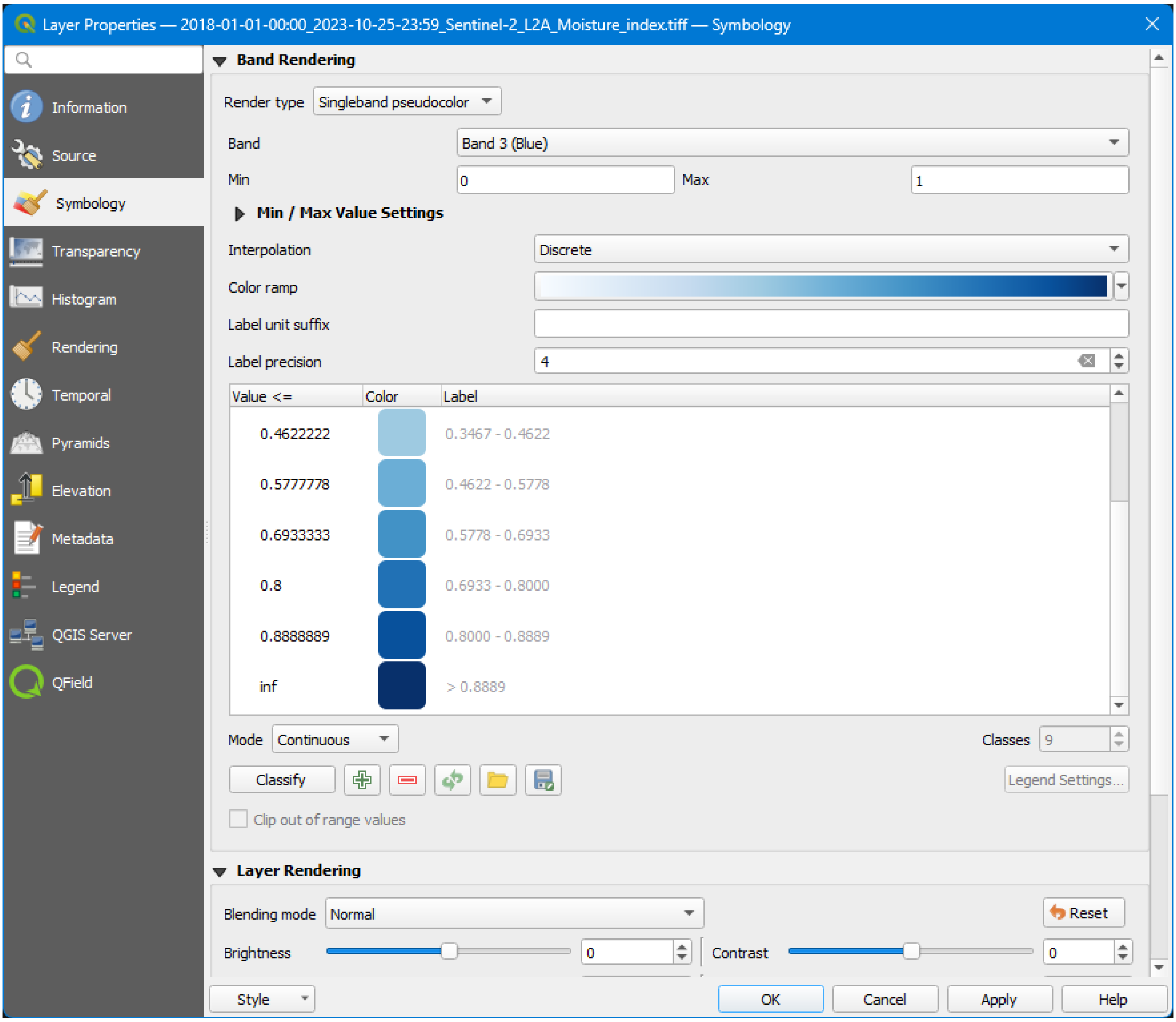
Raster file types

The most common file type used for raster data is the GeoTIFF (.TIFF). This is the general format for satellite imagery.

Styling raster layers

Notice that raster layer is made up of 3 bands: red, green and blue. Rasters can be composed of 1 or more bands containing different data. These bands can be styled to produce the required visualization.

- Double-click the layer to open its properties and switch to the `Symbology` tab.
- Notice the `Render type` is set to `Multiband color` displaying the red, green and blue bands in order. Change the `Render type` to `Singleband pseudocolor`.
- At `Band`, select `Band 3 (Blue)`.
- At `Interpolation`, select `Discrete`.
- Use a blue `Color ramp`.
- Click `Apply` and `OK` when finished.
- Select the `moisture-index` layer.
- Use the `Identify Features` tool to click on the map and view the results in the `Identify Results` panel.



Area of interest

The extent of the raster is larger than the island. We do not need the ocean area in the image so we'll clip it to coasts of Dominica. For this process we'll use the raster image and clip it using the `coastline.shp` file.

- From the menu bar, select `Raster --> Extraction --> Clip Raster by Mask Layer`.
- Select the `moisture-index` as the `Input Layer`.
- Select the `coastline.shp` file as the `Mask Layer`.
- Set the nodata value to 0.
- Select `Match the extent of the clipped raster...` and `Keep resolution of the input raster`.
- By default, the output is saved to a temporary file. Saved the clipped mask as `dominica-moisture-index.tif` to your project folder.
- Click `Run` to generate the output raster, then `Close`.

Copying styles

You will notice that the new raster has lost the pseudocolor styling from the original and has defaulted to the multiband color. To fix this, copy the style from the original layer.

- Right-click the `moisture-index` layer and select `Styles --> Copy Style`.
- Right-click the clipped raster layer and select `Styles --> Paste Style`.
- Be sure the disable the original layer.
- Re-order the layers to show the details you want.
- Save your project.

Adding labels

Labels can be added using the content of the vector layer's attribute table. We will add the parish names which were listed under `NAME_1` in the attribute table.

- Double-click the `parishes.shp` vector layer to open its properties.
- Go to the `Labels` tab.
- Select `Single Labels` from the dropdown.
- For `Value`, select `NAME_1`.
- Click `Apply`.

The labels can be styled using the various options available such as `Text`, `Formatting`, `Placement`, etc.

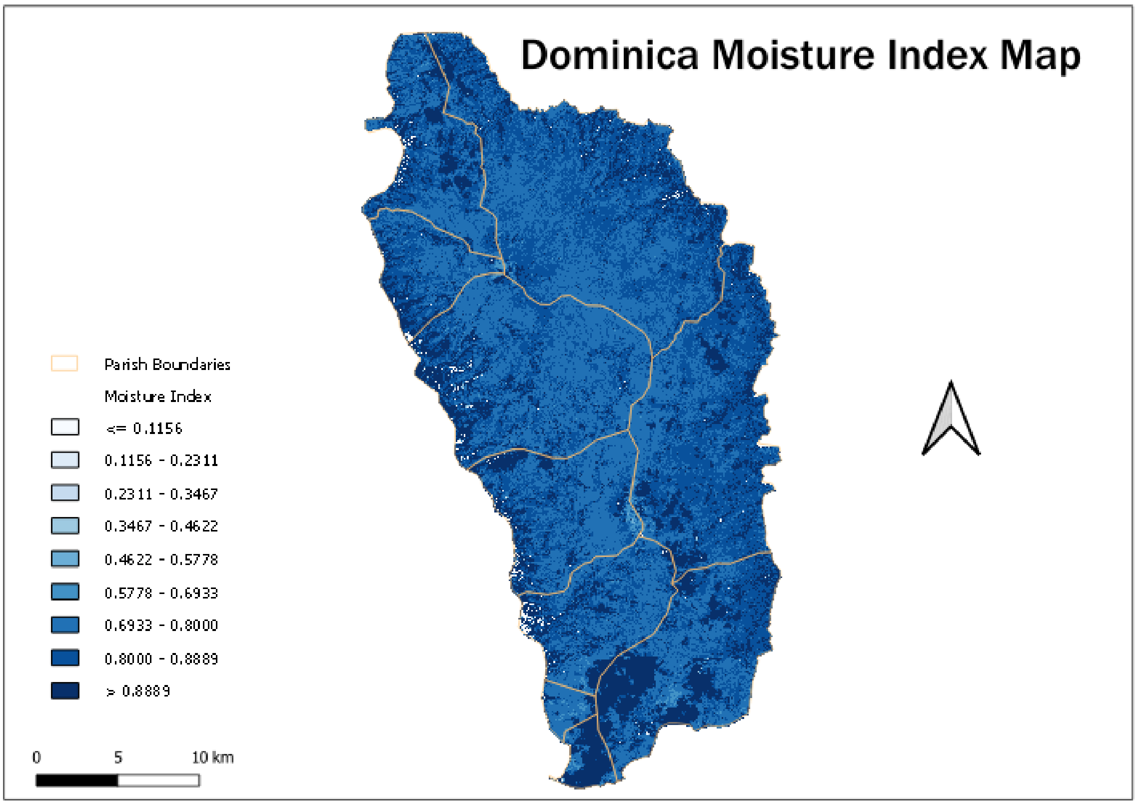
- Click `Apply to see the changes` and `OK` when done.
- In the main window, the labels can be activated by right-clicking the layer and selecting `Show labels`.

Next, we will create a map layout for printing.

Creating maps with QGIS

QGIS can be used to create printable maps with borders, scales, etc.

- From the menu bar, go to `Project --> New Print Layout`.
- Enter a name for the layout, e.g. `dominica_moisture_index` and click `OK`. A new window will open.
- In the new window, go to the menu bar and click `Add Item --> Add Map`. Draw a rectangle on the canvas to show the map. If you are not seeing the details you want, return to the main window and adjust the layers to display the required map details. Return to the layout window.
- To add a border, go to the `Item Properties` tab on the right and check `Frame`. Style the frame as desired.
- To add a title or any text, on the menu bar click `Add Item --> Add Label`. Draw the label text box. With the text box selected, go to `Item Properties --> Main Properties` and type the desired text. The text can be styled under `Appearance`.
- Add a scale bar.
- Add a north arrow.
- Add a legend to the map and style it as desired (edit, delete, spacing, etc.). Hint: the `Auto update` of `Item Properties --> Lengend Items` allows changes in the main window to be reflected on the map. Uncheck this if you are changing the legend entries yourself. Select `Only show items inside linked map`.
- Save your map layout by clicking `Layout --> Save Project` on the menu bar.
- Export the map: `Layout --> Export as Image` or `Export as PDF`.
- Close the map window when finished.
- You can reopen the layout from the main window menu bar: `Project --> Layouts` or use `Project --> Layout Manager`.



Sample map developed with QGIS.

On this page:

Digitizing features and editing attributes

Digitizing is the process of capturing areas of rasters (scanned maps, satellite images, etc.) in vector format. Attributes will need to be added to the captured features to properly describe and identify them.

Digitizing in Google Earth

Google Earth has both desktop and online versions. For simplicity, we will use the online version.

- In your web browser (Edge/Chrome) go to earth.google.com
- Drag and zoom the map to Dominica.
- Find an area of interest you wish to capture. Zoom in to this area.
- Click on the `Add path or polygon` icon at the top of the page.
- Draw a polygon around the feature/area you wish to digitize by clicking around the feature. To complete the process, double-click when you reach the start point again.
- Click `Save to project`.
- Save feature to `Local KML file`. Google's vector file type is KML/KMZ.
- Name the file.
- On the left, under `Local KML files`, go to the current project and click the option icon (3 dots). Select `Export as KML file`. This will download the file to your computer.

- Try using placemarks instead of polygons to mark points on the map.
- Download the KML file.

- Open the files in QGIS (drag them to the `Layers Panel` or add a vector layer).

Convert KML/KMZ to Shapefile in QGIS

- Right-click the .kml/.kmz layer in the `Layers Panel`. Select `Export --> Save Featuers As...`
- In the pop-up window, select `Format --> ESRI Shapefile`.
- For `File name`, browse to save the shapefile.
- Leave `CRS` as the default `EPSG:4326 - WGS 84`.
- Ensure `Add saved file to map` is checked.
- Leave all other default settings and click `OK`.

The new shapefile will show in the `Layers Panel`.

Plugins: Using web maps

QGIS uses plugins to add functionality to the software. One such plugin is QuickMapServices which allows basemaps from Google and other services to be loaded directly in the software.

To install a plugin:

- On the menu bar, go to `Plugins --> Manage and Install Plugins...`.
- Search for and install the `QuickMapServices` plugin.

To load Google Maps:

- On the menu bar, go to `Web --> QuickMapServices --> Google --> Google Hybrid`. The Google hybrid map will be added to the `Layers Panel`.

Digitizing can be done on the web map by following the procedure below. Georeferencing is not needed.

Digitizing scanned maps/rasters in QGIS

[Download topographic map]

The Layer will need to be [georeferenced] to appear correctly within the country map.

- Load the file into the `Layers Panel`.
- On the menu bar, go to `Layer --> Create Layer --> New Shapefile Layer...`.
- Name the file to save the layer to.
- Set the `Geometry type` to `Polygon` to digitize an area. Point features can be digitized as `Point` or `MultiPoint`. Linear features such as paths and boundaries may be digitized as `LineString`.
- Notice that the `Fields List` already has an integer `id` to identify each unique feature. Under `New Field`, add a new `string` field for the name of the area to be digitized.
- Click `OK` when you are finished.
- Ensure the `Digitizing Toolbar` is active.
- On the map layer, zoom to the area to be digitized.
- Click the `Toggle Editing` (pencil) icon.
- Click the `Add Polygon Feature` (green) icon.
- Click each corner of the area to draw the polygon. Right click to complete the polygon.
- Enter the feature details when prompted.
- On the `Digitizing Toolbar`, click `Save Layer Edits`.

Updating the Attribute Table in QGIS

You may need to add fields and data to a vector layer's attribute table. You can add and delete fields, edit data and perform various operations, using the attribute table's menu. To add a new field and data:

- `Right-click` the layer and select `Open Attribute Table`.
- Click the `New field` icon.
- In the popup dialog box, give the field a name, select an appropriate data type and length. You may also add a comment to describe the field.
- Click `OK` when done.
- Enter the desired data into the new field of the attribute table.
- Click the `Save edits` icon.

Adding data from GPS devices

[Download GPS data]

Add XY Data (GPS data):

- Go to `Layer menu --> Add --> Add Delimited Text Layer`.
- Set the following:

> Input = `FarmCoordCSV` file.

> Specify the output Name and Location.

> X and Y fields = `Xcoord` and `Ycoord`, respectively.

> CRS = `EPSG 2002: Dominica 1945 / British West Indies Grid`.

> Geometry Definition = Point coordinates.

- Click `OK` to finish the import.

- Export the temporary XY event layer to a shapefile.

On this page:

Converting vector and raster data

In this section, we will use the `Processing Toolbox` to access tools, rather than using the menu bar. Ensure that the `Processing Toolbox Panel` is visible.

Convert vector to raster (rasterize)

Download: Dominica rainfall vector file

- Load the vector file.
- In the `Processing Toolbox` search field, type `rasterize`.
- Double-click `Rasterize (vector to raster)`.
- Select `rainfall` as the input layer.
- Select `RAINFALL` as the `Field to use for a burn-in value`. This will ensure that the rainfall values are added to the output.
- Select `Pixels` as the `Output raster size units`.
- Enter `100` for the `Width` and `Height`. A higher number produces a higher resolution and better visualization.
- Set `Output extent --> Calculate from Layer --> coastline.shp`.
- Set the new file name under `Rasterized`.
- Click `Run` to generate the raster layer.
- The new raster will be visible in the `Layers Panel`.
- Click `Close` when finished.

Convert raster to vector (vectorize)

Convert the new rainfall raster back to vector format.

- In the `Processing Toolbox` search field, type `polygonize`.
- Double-click `Polygonize (raster to vector)`.
- Select the rainfall raster as the input layer.
- The rainfall values used in the vector conversion above will be added to the new vector. Type `rainfall` in `Name of the field to create`.
- Set the new file name under `Vectorized`.
- Click `Run` to generate the vector layer.
- The new vector will be visible in the `Layers Panel`.
- Click `Close` when finished.

On this page:

Georeferencing

Download topographic map

Setting Project CRS:

- `Project --> Properties --> CRS`.
- Search for the CRS of interest (e.g. WGS 84) and Apply.

Georeferencing

- Set the project CRS.

Open the georeferencer tool:

- On menu bar, go to `Layer --> Georeferencer`.
- In the resulting `Georeferencer` window, go to `File --> Open Raster` and browse to add the image or layer to be georeferenced.

Now set the georeferencing transformation settings in the `Georeferencer` window:

- Go to: `Settings --> Transformation settings`.
- Set `Transformation type = linear`.
- `Resampling method = Nearest neighbour`.
- Target SRS: click the `Select CRS` button and then select the CRS native to the image to be georeferenced.
- Specify output file name and location.
- Check `Load in project when done`.
- In the `Georeferencer` window, click the `Add Point` tool on the toolbar and click the location for the first GCP. The `Enter Map Coordinates` dialog opens.
- Enter the X and Y values for the GCP and press `OK` (ensuring that the CRS is the same as specified earlier).
- Continue to place other GCPs following the same procedure.

Supporting data:

View GCPs map

GCP information:

Label	Description	Lon	Lat
0	Junction of Granby St & Bay St (Portsmouth)	-61.455949	15.573490
1	Junction of Castle Bruce Rd & East Coast Rd	-61.259719	15.434244
2	T-Junction on Goodwill Rd	-61.388860	15.315476

- To delete a point, click on the `Delete Point` tool on the toolbar and click on the point you want to delete.
- You can also move the GCP point to a desired location by clicking on the `Move GCP Point` tool and clicking on the target point and move it to where you want.

Once about three ground control points are added, you may see the georeferencing error as a red line coming out of the points. The error in pixels can be seen also in the `GCP table` in the `dX(pixels)` and `dY(pixels)` columns. Error in pixels should not be higher than 10 pixels. If it is, you should review the points you have digitized and the coordinates you have entered to find what the problem is.

The GCPs can be saved for later use:

- Go to `File --> Save GCP points as...`. Specify the name and location and save.

To complete the georeferencing:

- Go to `File --> Start Georeferencing`. The georeferencing is completed and the layer is added to the map canvas.

On this page:

Geodatabase basics

Introduction

A **database** is a collection of structured data on a computer system which is usually manipulated by **database management system (DBMS)** software. The DBMS allows editing and **querying** the database to produce the desired information. A **geodatabase** or **spatial database** is a special type of database for storing geographic or spatial data. This type of data includes geographic coordinates, such as latitude and longitude, and the geodatabase can store geometry parameters such as points, polygons and lines. The geodatabase also allows special functions such as spatial queries, e.g. finding features which are close to a point or enclosed within a polygon, and several other spatial functions.

The data in a database is normally arranged in tables, represented as rows and columns. A row represents a **record** which is all the data related to an **entity**, e.g.

ID	Farm	Area
1	Roberts Plantation	200
2	Victoria Farms	500

Each column in the data table represents an **attribute** of the entity. A single attribute within a row can be referred to as a **field**. Notice that each row has a unique ID which identifies it from any other row. Such an attribute is known as a **key**. In this table, `ID` is the **primary key**.

A table is also known as a **relation**. A database which uses the tabular structure with entities, attributes and keys is known as a **relational database**. A relational database contains several tables which are related to each other and are linked by their keys. There are several types of databases, each with their pros and cons and suitability for various purposes. We will focus on the relational database for the storage and retrieval of spatial data.

There are several databases systems with support for spatial data, including SpatiaLite and PostgreSQL with PostGIS.

As a database becomes very large, querying the data will become slower. Queries can be sped up by using **indexes**, e.g. in the previous table, an index can be created on `Farm` to allow faster searching by farm name.

About GeoPackage (.gpkg)

GeoPackage is a light-weight spatial database file format which handles both vector and raster data. The single file format is easy to use across devices and supports spatial indexing to speed-up queries.

Datatypes

Data stored in databases confirm to specific data types. Some common datatypes are:

- Integer (negative and positive numbers)
- Float (decimal numbers)
- Boolean (true/false)
- String (text)
- Date (formatted date values)
- Geometry (spatial features and coordinates)

Normalization

A database must be properly structured to be useful and efficient. One way to do this is to ensure that data in fields are reduced to the simplest form, e.g. create separate fields for first name and last name rather than full name. Also, the data should not be redundant or duplicated, e.g. if several farms are under a farming project, data about the project should not be stored with the farm data but rather in a separate table containing project data. This separation and simplification is known as **normalization**.

Querying databases

Databases may use graphical interfaces and/or coding to retrieve or update data. The standard code for querying relational databases is **SQL**. The syntax for SQL looks like this:

```
SELECT * FROM Farms WHERE ProjectName = 'Cocoa and coffee'
```

This statement reads as 'select all data from the table Farms that match the project name Cocoa and coffee'.

Working with databases

QGIS can connect to and retrieve data from existing external databases. So if you have a PostgreSQL or other compatible database, QGIS can link with this database to perform spatial analysis. The `Browser Panel` provides built in functions for compatible databases. The GeoPackage is another convenient file type for creating a local database which can be easily shared. The GeoPackage can also be queried with SQL statements.

We will create, edit and query databases and integrate with QGIS.

Creating a geopackage database

Geopackages are spatial database files which can store a variety of data associated with a project. We will save the project, layers and associated styles to a geopackage.

In QGIS, create a new project.

[Download and extract estates and soils vectors zip file]

- Rename the layers to estates and soils respectively.
- Apply a categorized symbology with random colors to each layer.

Package the layers:

- In the `Processing Panel`, search for `package` and open `Package layers`.
- Add the 2 layers, saving the style and metadata.
- Save the file.

Connect to the geopackage:

- In the `Browser Panel`, right-click `GeoPackage` and select `New connection...`
- Browse and connect to the geopackage.

Load the geopackage layers:

- Remove the original layers from the `Layers Panel`.
- Add the layers from the geopackage. Notice they have kept all formatting.
- Check the source to confirm that they came from the geopackage.

Saving the project to the geopackage:

- Go to `Project --> Save to --> GeoPackage...` and select the geopackage.
- Complete the dialog box.
- Close the project.

Opening a project saved in a geopackage

- Go to `Project --> Open from --> GeoPackage...`.

Spatial queries

Apart from regular SQL queries, spatial databases allow special spatial queries such as proximity of features or whether they overlap. We will execute SQL queries on the geopackage layers.

- In the `Browser Panel`, expand the geopackage.
- Right-click the `estates` layer and select `Layer Properties...` to preview the associated data.
- Close the dialog box.
- Right-click the `estates` layer and select `Execute SQL...`.
- Execute the following SQL query:

```
SELECT * FROM estates WHERE estate_typ = "Large Estates";
```

- Load the result to visualize it.
- Execute the following SQL query:

```
SELECT * FROM estates JOIN soils ON ST_EnvIntersects(estates.geom, soils.geom) WHERE estates.estate_typ = "Large Estates" AND soils.type = "Kandoid latosols";
```

- Load the result to visualize it.

Working with PostGIS

alwaysdata is a site which allows you to easily host online databases. We will use this site to demonstrate the basic workings of PostgreSQL database with PostGIS extension. The free account allows data storage up to 100 MB and will be terminated over a period of inactivity.

- Go to https://www.alwaysdata.com/en/ and create a free account. Remember your passwords!
- Once the account has been created, select `PostgreSQL` under `Databases` and `Add a database`. You can add databases and users for your account this way.
- On the database page, enter a name for the database under `Details`.
- Under `Options --> Extensions`, select `PostGIS` and `Submit` the form.
- Take note of the `PostgreSQL host` name at the top of the page, the database name, database username and password which you created.

The database is now setup and can be manipulated using the web program phpPgAdmin. You will see a link to this under the host name and version at the top of the page.

- Click the link to open phpPgAdmin.
- Use the user name and password you created for the database to login. If you forget the password, go back and change it on the users tab of the database account.
- In phpPgAdmin, view the navigation tree on the left and notice your PostgreSQL database. Expand to `Schemas --> public --> Tables`. Note that no tables have been created in the database as yet. We will create a table with geometry to store farm data.
- To make a table to store data, click on `Tables` in the navigation tree and `Create table` in the main pane.
- Enter the following:
  - Name: farms
  - Number of columns: 4
  - Comment: Basic data for each farm plot.
- Click `Next`.
- Now create the columns (column names must not have spaces). We'll give each column a name, data type and comment. Comments are descriptions to help users.
  1. id, serial, not null, unique key, comment: Primary key, auto-increments.
  2. name, text, not null, Name of the farm.

3. type, text, Type of activity (arable, pastoral, mixed).
4. geom, geometry, lon lat coordinates.
5. description, text, General details.

- Click `Create`.
- Once the table has been created, click on `farms --> Insert` to enter data. The **id** field will be generated by the database. Enter the name, type, geometry and description as shown below. After adding data for a row, click `Insert & Repeat` to add a new row and `Insert` after the last row.

Name	Type	Geometry	Description
Fresh Farm	Arable	POLYGON((-61.37360927550622 15.41470178191764, -61.37143506044097 15.41308112202391, -61.36730690626399 15.41465892839792, -61.36856720412191 15.4169977323299, -61.37360927550622 15.41470178191764))	Vegetable farm with vending facility.
Henderson Rabbit Farm	Pastoral	POINT(-61.3281011 15.2668005)	Small rabbit farm.
Greyson's Farm	Mixed	POLYGON((-61.34845586256422 15.23028220735083, -61.34857223001723 15.22964621301943, -61.3483681718734 15.22930191070718, -61.34794025920919 15.22962960452875, -61.34845586256422 15.23028220735083))	

- Once the data has been added, select the `farms` table and click `Browse` to view the data.
- Notice the `geom` column has been converted to Well Known Binary (WKB) format.

Connecting QGIS

We will now link QGIS to the database and retrieve the table.

- Start a new project in QGIS.
- In the `Browser Panel`, right-click `PostgreSQL` and select `New Connection`.
- Enter the following:
  - Give the connection a name (this could be the database name on alwaysdata).
  - Leave Service empty.
  - Host: Enter the PostgreSQL host (found at the top of the database page on alwaysdata).
  - Leave the Port as 5432.
  - Database: Enter the database name from alwaysdata.
  - SSL mode: require.
  - Leave Session ROLE empty.
- Under `Authentication --> Configurations`, click the plus sign.
  - Enter a name for the authentication configuration (this could be the database name).
  - Select `Basic authentication`.
  - Enter the username and password for the **database user** you created on alwaysdata. You can view the password by clicking the gear icon next to the user on alwaysdata.
  - Click `Save`.
- Click `Test Connection`.
- Check the following boxes:
  - Only look in the 'public' schema
  - Also list tables with no geometry
  - Allow saving/loading QGIS projects in the database
  - Allow saving/loading QGIS layer metadata in the database
- Click `OK`. Your database will be connected.

Loading database tables

- In the `Browser Panel`, under `XYZ Tiles`, drag `OpenStreetMap` to the `Layers Panel`.
- Expand `PostgreSQL` in the `Browser Panel` and drag the `farms` tables to the `Layers Panel` to visualize them on the map.
- Open the `Attribute Table` to view the data.

You have successfully loaded data from an online database.

Saving the project to the database.

Saving the project to the database:

- Go to `File --> Save to --> PostgreSQL....`
- Select the Connection, Schema, give the Project a name and click `OK`.
- Close the project
- Login to your phpPgAdmin on alwaysdata and expand to your database public schema.
- Under `Tables`, click on `qgis_projects`. You should see your farms project (you may need to click `Browse`).

Opening a project saved in a database

- Go to `Project --> Open from --> PostgreSQL....`
- Complete the dialog box and click `OK`.

On this page:

Spatial Analysis

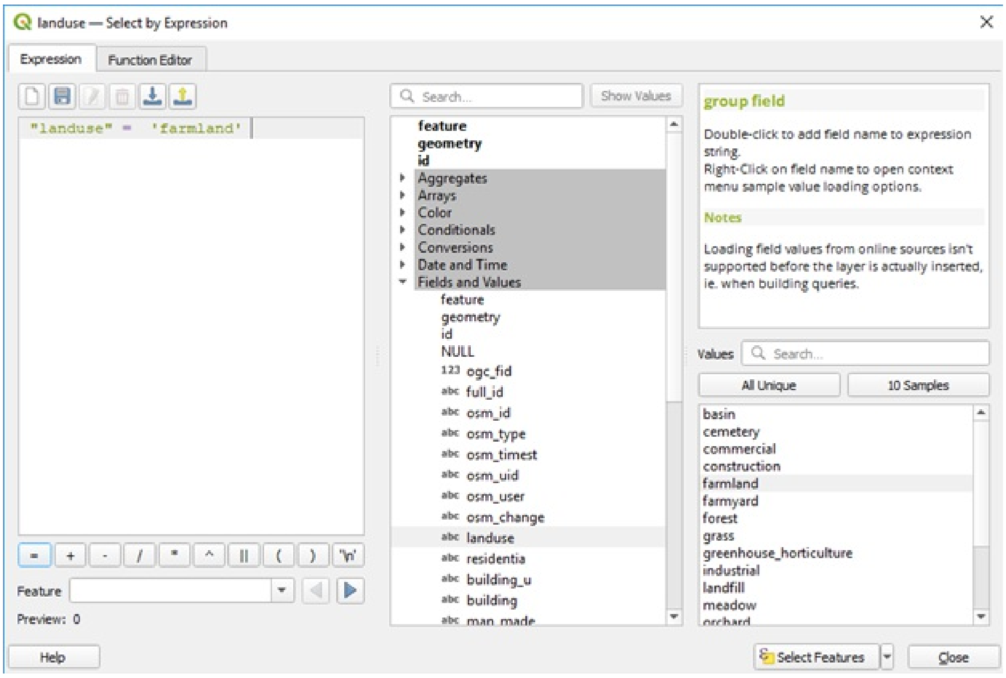
Esri Land Cover

Download the zip file and extract the contents to your project folder.

Download datasets

Extracting features by attribute

- Open a blank project document.
- Add the `landuse` layer.
- Right-click the layer and select `Properties`.
- Click the `Information tab` in the properties dialog window.
- Check and confirm that the CRS is `WGS84`. You can also check a layer's CRS by right-clicking on it and selecting `Layer CRS`.
- Open the attribute table and click on the `Select features using an expression` tool to open it.
- In the resulting dialog, expand the `Fields and Values` item in the middle pane, double-click `landuse` to add to the expression box (left pane).
- With `landuse` still selected, click on `All Unique` under the `Values` pane on the right.
- In that pane, double-click `farmland` to add to the expression box. Click `Select Features` on the lower-right to select the features.



On the title bar of the attribute table, or in the map canvas, you can see the selected features.

- On the lower left of the attribute table, click in the box that says `Show All Features` and select `Show Selected Features`. How many features are selected?

You will now create a layer of farms from the selected features.

- Right-click on the `landuse` layer and select `Export --> Save Selected Features As`. Specify the location and file name and save.
- Under `Format`, choose `ESRI shapefile` and click `OK`.

- Now, in the attribute table, choose to `Deselect all features`.
- Drag and drop the `OpenStreetMap` under the `XYZ Tiles` in the `Browser panel`.
- Zoom in to inspect the location of the farms and ascertain if accurate.
- Remove the OpenStreetMap layer.

Reprojecting

The current data is in WGS84 Geographic Coordinate System (GCS). Sometimes, you may need to change the CRS of data from different sources into a common CRS. You may also need to add a projected coordinate system to dataset for some spatial analysis. You will change the CRS of the farms dataset. Currently, the project CRS is the same as that of the first layer you added.

- Right-click `Farms --> Export --> Save Features As`. Specify file name and location and choose `ESRI shapefile` format. In the CRS box, click the `Select CRS` button.
- In the resulting dialog, in the `Filter` box, type Dominica to search. Choose the `Dominica 1945/British West Indies Grid (EPSG: 2002)` and press `OK`.
- Press `OK` again to save the file.

A layer with projected coordinate system (PCS) can be reprojected (transformed) to another PCS. Try transforming the Farms layer with the Dominica 1945 / British West Indies Grid to WGS84 UTM Zone 20N.

- In the `Processing Toolbox`, type `project` in the search bar.
- Double-click `Reproject layer`.
- In the resulting dialog, choose the right layer to be projected as input layer.
- For the target CRS, search for `UTM` and scroll to choose `WGS 84 / UTM zone 20N` and click `Run`. The reprojected layer would be added to the map canvas.

Extract Centroids

When you map farms as polygons, you may not need to map them as points. You can extract the central point of the farm. Try this.

- In the search bar of the `Processing Toolbox`, type `centroid`. * Choose `Centroids` under the `Vector Geometry`.

- Specify `Farms` as the input layer. Click on the small arrow in the box to the right of the Centroids box and choose `Save to file`. Specify the file name and save the layer as a shapefile.
- Click `Run` in the Centroids dialog box. The extracted centroids layer is added.
- Zoom in and pan around to explore the centroids. Open the attribute table and note that the centroids layer inherited the attributes of the farms layer.

Calculate Area and Perimeter

Once farms are mapped as polygons, you can calculate the area or perimeter of the farm.

- Go to `Project --> Properties --> General tab`.
- Under `Measurements`, choose `meters` for `units for distance measurement` and `acres` for `units for area measurement`.
- Leave the `Display coordinates` in `map units`.
- Ensure that the project projection is in `WGS 84 / UTM Zone 20N`.
- Click `Apply` and `OK`.

- Open the attribute table of the `farm` layer with the UTM Zone 20N projection.
- Click on the `Open field calculator` button on the attribute table toolbar and choose to `Create a new field`.
- Name the field `Area`; `output field type = decimal number (real)`; `precision = 2`.
- To calculate the field, expand the `Geometry` item in the Show Values box.
- Double-click `$area` to add to the expression box and click `OK`. The calculated area should be added to the table (last column).

- In the attribute table, toggle the editing mode off and `Save edits`.

Remember the unit is same as you specified in the project properties (acres).

- Repeat the process in the `farm` layer with the Dominica 1945 / British West Indies Grid projection.

- Compare the area for the farm with `ogc_fid 142`. Are they the same?

Querying attributes

Make a definition (attribute) query in any of the layers to identify farms with area less than or equal to 2 acres; and those larger than or equal to 10 acres.

Generate statistics

To generate simple statistics for the field `Area`:

- In the `Processing Toolbox` search bar, search for `stat`. Choose `Basic statistics for fields` under the `Vector analysis` section.
- Choose the farm layer as the input layer, and `Area` as the `Field to calculate statistics on`. We will keep this as a temporary file so click `Run`. Once completed, the stats info is displayed under the log tab.

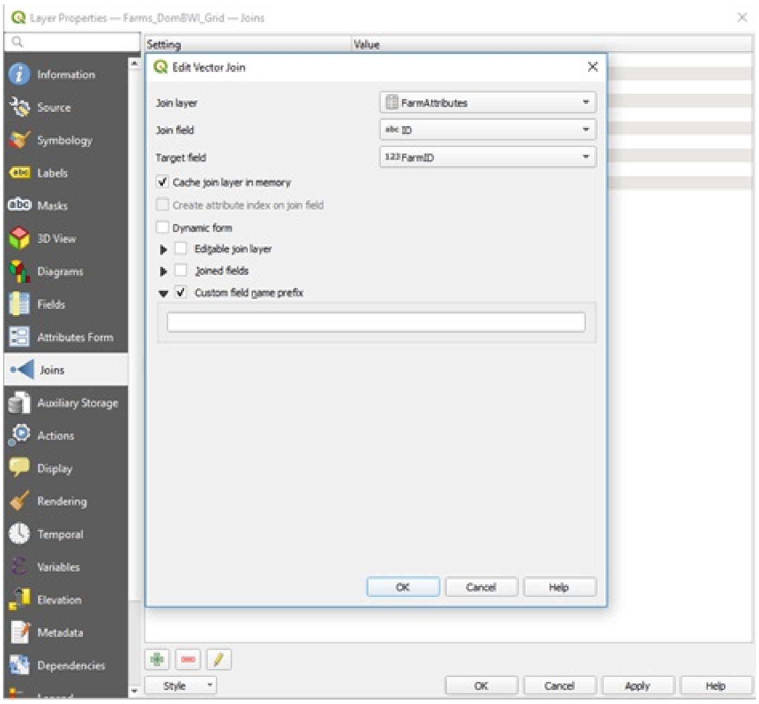
Update farm records with tabular join

Let’s work with the layer having the UTM Zone 20N projection (so remove the other farm layers, if any).

- Open the `attribute table` of this layer and use the `Field Calculator` to insert a `Field` with name `FarmID`.
- Expand the `variable` item and double-click `row-number` to add to the expression box. Click `OK`. Row numbers are assigned as IDs under the field `FarmID`.

We will use this ID to join a hypothetical tabular information collected from the farms.

- In the `Browser pane`, browse to your data folder, drag and drop the `FarmAttributes.csv` file to the map canvas (it is added to the layers panel).
- Right-click the `Farms --> Properties --> Joins`.
- In the resulting dialog, complete the required fields as shown in the figure below.



- Click `OK` and `OK` again to complete the join.
- Open the `attribute table` of the `Farms layer` and ensure that the fields are joined. The join is temporary, so a new shapefile can be created to make it permanent.
- Right-click on the `Farms layer --> Export --> Save Features As…` save it as shapefile and specify file name and location.
- Remove the `FarmAttributes.csv` file.

Estimate yield (kg/acre)

In the new layer with the join fields, you have average yield of the main crops. Multiplying this by the area should give you an estimated yield.

- Open the `attribute table` of the newly created `layer --> Field Calculator`. Give a suitable name to the new field, choose `decimal number (real)` with `precision = 2`.
- Expand the `Fields and Values` item and make the expression: `Area * AvgYield`.
- Click `Ok`.
- Stop edits and save edits.

The estimated yield of each main crop for each farm is provided in the last column.

- Make a definition query to select female farmers who grow `dasheen`. Your query should look like this: `"Sex" = 'F' AND "MainCrop" = 'dasheen'`. The query result can also be used to answer the question which female farmer has the largest/smallest area of dasheen.

Generate group statistics

- Search again for `stat` in the `Processing Toolbox` and choose `statistics by category`.
- In the resulting dialog, choose the *newly created join layer* as input layer; choose the *estimated yield* as the field to calculate statistics on (this should be numeric).
- Click on the dots next to the box for `Field(s) with categories` and tick `maincrop` and `sex`. Click `Run`. The output would be seen in the Layers panel as a table. Right-click on it `--> Open Attribute Table` and view the result, which shows estimated yield statistics by sex and main crop. The count field is the same as frequency. * To save the temporary group statistics layer, right-click and choose make permanent (or export).
- Save your project.

Fix geometry and count points in polygon

Some polygon datasets have geometry errors that might only show up during geoprocessing such as overlay. Here, we want to count the number of farms in a given soil class or attributes. We will use the `Farm centroids layer`. Add the `lsd_soil shapefile`. Familiarize yourself with the attribute table. In the `Processing Toolbox`, search for `point` and choose `Count points in polygon` under the `Vector analysis` item.

- Complete the dialog box as follows: Polygon = lsd_soil layer; Points = Farmcentroid; Count field name = default.
- Click Run.

You may get an error message that the soil layer has geometry errors. You can check which polygons have geometry errors (normally holes in the layer) by using `Check validity` (under vector geometry) – search for valid in the `Processing Toolbox`.

- In the check validity dialog, choose the soil layer as input and check `Ignore ring self intersections`.
- Click `Run` to keep all outputs as temporary.

Check the valid and invalid outputs visually.

- Repeat the process without checking the `Ignore ring self intersections`. Are the outputs similar?

Let's fix the geometry error.

- In the `Processing Toolbox`, find `Fix geometries`: Input layer = lsd_soil; Repair method = structure; Fixed geometries (choose to save the file with appropriate name).
- Click `Run`.

- Now use the soil layer with fixed geometry and run again the `Count points in polygon` algorithm.

- If successful, open the `Count` layer attribute table. Note that this operation keeps the attributes of the soil layer and adds a field with the count of soil points.

- Make an expression to select `NUMPOINTS > 0`.
- Export the selected features to a new shapefile and choose to add the project.
- Open the attribute table and explore it.

You will change the field name of NUMPOINTS to something more meaningful.

Edit Field Name

- Search for `Rename` in the `Processing Toolbox` and choose `Rename field`.
- In the resulting dialog box, choose your `Count layer`, choose `NUMPOINTS` for the `Field to rename`, and give the new name in the `New field name` box (e.g., NumFarms).

How many farms are in the soil type *Kandoid latosol* or *Young soil* (check the Field called *type*).

Polygon-Polygon Overlay

- On the menu bar, go to `Vector > Geoprocessing tools > Intersection`. Input layer = soil layer with fixed geometries; Overlay layer = Farms layer with the attribute joined. Note: In the `Input fields to keep`, you can choose which fields in the attribute table of the input layer you want to preserve in the resulting overlay layer. Similarly, in the `Overlay fields to keep` box, you can choose the fields in the overlay layer to be kept in the resulting layer. Leave these as default for now.
- Click Run.

In the resulting layer, examine the attributes. When you do a polygon-polygon overlay, it is always a good idea to re-calculate the geometric area of each polygon feature and not to rely on the previous area.

- Use the `Field Calculator` to calculate the area in a new field and compare the values with the old area in the attribute table.
- Now, run `Statistics by categories`, using the newly calculated area as the `Field to calculate statistics on`. You can choose the field `type` as the `Field(s) with categories`.
- Click `Run`.

Explore the result. Which two soil types are commonest under the farms in the study area? Which soil covers the largest area of farmlands?

- Close the table.
- Re-run the `Statistics by category` again, this time add `MainCrop` and `type` to the `Field(s) with categories` box.

Note that this output is temporary (you may make it permanent by saving it if you want). Explore the result. Which crop has the largest area coverage (and on which soil type does it occur)? Ensure that the answer is *dasheen* on *Young soils* (if you are not sure, sort the field called *sum*).

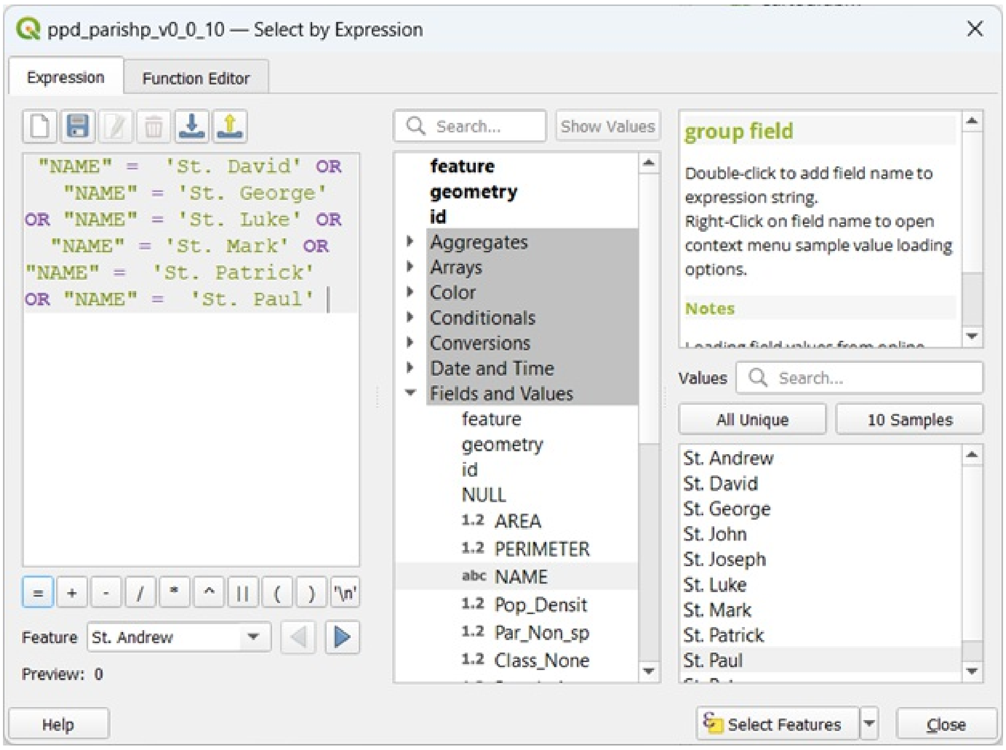
Geometric selection

So far, you have practiced attribute-based selection. Now you will select features based on their geometric or geographic relationship with features in another layer.

- Add the `lsd_Rivers` layer and `ppd_Parish` layer.

You will subset the Parish layer and use the subset to clip an area of interest from the Rivers layer. Open the attribute table of the Parish layer and select the southern parishes that overlaps with the farms.

- Write an expression that looks like in the image below.



- Once the appropriate parishes are selected, export the selected parishes to a new shapefile and choose to add it to the project.
- Remove the original parish layer.

Because the Rivers layer is large (covers the whole country), you will clip it to the study parish layer.

- On the menu bar, go to `Vector > Geoprocessing tools > Clip`.
- Choose the Rivers layer as input; the subset parish layer as the overlay layer and click `Run` (if you get error, fix the geometry first and run the clip algorithm again).
- Once successful, remove the original Rivers layer. Make the result permanent and save your project.

Select by location

[ppd_rivers dataset]

- On the menu bar, go to `Vector > Research Tools > Select By Location`. Complete the following: `Select Features from`: Farms with the attribute joined (the polygon layer), `Where the features`: `intersect`, `By comparing to the features from`: the clipped Rivers layer.
- Click `Run`.
- Open the `attribute table` of farms layer and choose to `show selected features`. How many farms intersect rivers?
- In the map canvas, turn off all the layers except the farms layer, zoom in to see which farms were selected.

Select within a distance

You will now select features based on distance to features in another layer. Example, you might be interested in which farms are within a given distance of a protected area.

- In the `Processing Toolbox`, expand the `Vector Selection --> Select within distance`. `Select Features From`: Farmcentroids; `By comparing to the features from`: clipped Rivers layer; `Where the features are within`: `50 meters`
- Click `Run`.
- Open the Farmcentroids attribute table and check how many features are selected to be within 50 meters of rivers.

Extract raster values to points

You might be interested in the elevation of a given farm location. You can extract the elevation from a digital elevation model (DEM) using point features.

- Add the `Voidfilled_DEM` raster data and then the `Farmcentroids` layer.

Note that the DEM layer is unprojected and has WGS84 GCS.

- In the `Processing Toolbox`, go to `Raster Analysis --> Sample raster values`. Input layer: Farmcentroids; Raster layer: Voidfilled_DEM; Output column prefix = ELEV_
- Click `Run`.
- Open the Farmcentroids attribute table and check the last column or field to see the extracted elevation values for the farm locations. You may use the `Identify tool` to explore the elevations of a few farms.

Zonal Statistics

- Add the Void_filled DEM raster data. You can reproject (warp) to WGS84 / UTM Zone 20N.
- Add the Parish layer you used previously to the map.
- In the `Processing toolbox`, search for 'zonal' and choose `Zonal statistics`.
  - Input layer: parishes;
  - Raster layer: DEM;
  - Output column prefix: ELEV_
  - Statistics to calculate: click the 3 dots and choose Mean, Minimum, Maximum
- You may choose to save the Zonal statistics output layer.
- Click Run.
- Open the attribute table of the resulting zonal statistics output layer and look for the statistics calculated (in the last columns, with the prefix **ELEV_**).

Zonal Histogram

For each Dominica parish, you will calculate zonal histogram to summarize the pixel count of each land cover/use class in the ESRI land cover/use layers for the 2018 and 2022.

First, clip the land cover/use layer with the coastline layer.

- In the `Processing toolbox`, search for 'clip' and choose `Clip raster by mask layer` under the GDAL (Raster extraction) function.
- Input layer = land use/cover raster. Mask layer = coastline. Ensure that the `Match the extent of the clipped raster to the extent of the mask layer` is checked.
- Click Run.
- Make the output or result permanent by exporting it as a `Geotiff`.
- After saving the clipped layers, remove the temporary clipped layers and the original land use/cover layers. You may as well remove the coastline layer.
- Colour the clipped layers by assigning the land use/cover classes obtainable from the Class Definitions table below.
- Double-click one of the clipped layers to open the property window.
- Click the `Symbology` tab.
  - Render type = Paletted/Unique values;
  - Click Classify at the bottom left to see the classes and labels.
  - Under `label`, double click on a class number and type in the right name obtained from the metadata. The class numbers are below:

Class definitions table

Class (Value)	Name	Description
1	Water	Areas where water was predominantly present throughout the year; may not cover areas with sporadic or ephemeral water; contains little to no sparse vegetation, no rock outcrop nor built up features like docks; examples: rivers, ponds, lakes, oceans, flooded salt plains.
2	Trees	Any significant clustering of tall (~15 feet or higher) dense vegetation, typically with a closed or dense canopy; examples: wooded vegetation, clusters of dense tall vegetation within savannas, plantations, swamp or mangroves (dense/tall vegetation with ephemeral water or canopy too thick to detect water underneath).
4	Flooded vegetation	Areas of any type of vegetation with obvious intermixing of water throughout a majority of the year; seasonally flooded area that is a mix of grass/shrub/trees/bare ground; examples: flooded mangroves, emergent vegetation, rice paddies and other heavily irrigated and inundated agriculture.
5	Crops	Human planted/plotted cereals, grasses, and crops not at tree height; examples: corn, wheat, soy, fallow plots of structured land.
7	Built area	Human made structures; major road and rail networks; large homogenous impervious surfaces including parking structures, office buildings and residential housing; examples: houses, dense villages / towns / cities, paved roads, asphalt.
8	Bare ground	Areas of rock or soil with very sparse to no vegetation for the entire year; large areas of sand and deserts with no to little vegetation; examples: exposed rock or soil, desert and sand dunes, dry salt flats/pans, dried lake beds, mines.
9	Snow/ice	Large homogenous areas of permanent snow or ice, typically only in mountain areas or highest latitudes; examples: glaciers, permanent snowpack, snow fields.
10	Clouds	No land cover information due to persistent cloud cover.
11	Rangeland	Open areas covered in homogenous grasses with little to no taller vegetation; wild cereals and grasses with no obvious human plotting (i.e., not a plotted field); examples: natural meadows and fields with sparse to no tree cover, open savanna with few to no trees, parks/golf courses/lawns, pastures. Mix of small clusters of plants or single plants dispersed on a landscape that shows exposed soil or rock; scrub-filled clearings within dense forests that are clearly not taller than trees; examples: moderate to sparse cover of bushes, shrubs and tufts of grass, savannas with very sparse grasses, trees or other plants.

Credit: [Sentinel-2 10m Land Use/Land Cover Time Series]

Change colours of the layers: Once the class labels are assigned, you can double-click individual colours beside the labels and change them to suit your preference.

- Try changing the colour of one class, click Apply to see how it looks like on the map. Complete the styling of the map.
- You can save the style to use in the future. At the lower left of the property dialog, click `Style --> Save Style` and browse to save it at a desired location.
- To use the saved style on a different layer, open the property dialog of the layer to be styled, click `Style --> Load style` and browse to the saved style.

Alternatively, you can click OK in the current property dialog to exit. You can then copy the style:

- Right-click the stylized layer –> `Copy style`.
- Then, right-click the other layer –> `Paste style`. Explore the maps for accuracy based on your local knowledge.
- Add the parishes layer. In the `Processing toolbox`, search for 'zonal histogram'.
  - Raster layer = one of the land use/cover layers.
  - Vector layer containing zones = Parishes.
  - Leave the rest as default.
- Click Run.
- Open the output table of the result, look for the columns with `HISTO_` as the suffix to see the number of pixels (or pixel count) for each land use/cover class in each parish.
- Calculate area of crop:
  - Check the pixel size of the land use/cover layer under the information tab in the properties dialog. Note that it is 10 m. Confirm this information with the metadata of the land use/cover layer.
    - Go to `Project --> Properties --> General` tab. Ensure that the units for area measurement is in meters. Close the project property dialog.

The land use/cover class 5 denotes crops. Let's calculate the area of crops in each parish.

- Click on the `Field Calculator` on the toolbar of the attribute table.
- Ensure that the `Create a new field is checked`.
- Name the new field **CropArea**
  - Datatype = Decimal number
  - Field length = 10
  - Precision = 2
  - In the expression box, multiply the `HISTO_5` field by 10 by 10 (the cell area of the land use/cover layer as seen from the metadata). Your expression should look like:

    > “HISTO_5” * 10 * 10

- Click OK to evaluate the expression.
- Check the result in the attribute table (note that the area is in square meters).

Explore the results.

- Which parish has the largest/smallest crop area?
- Compute area of trees and indicate which parishes have the largest/smallest area of trees.

You can also map the parishes based on any of the attributes (e.g. crop area or number of trees).

Raster Calculator: you can use the raster Calculator to apply mathematical functions to one or more raster layers. Here, you will multiply the 2022 layer by 10 or 100.

- In the `Processing toolbox`, search for calculator and choose `Raster calculator`.
- In the dialog box, double-click on the 2022 raster layer to add it to the expression box.
- Click * to add to the box and type 10 (or 100, whichever you prefer) into the box.
- Scroll down to set the cell size or the layer from which cell size and CRS should be obtained.
- Click Run.

Examine the output to note the cell values have changed but the data (map) itself is not changed. This is simply a reclassification.
