VETFARM

Monitoring Pistachio Orchards

INTRO TO GIS

About

Syllabus

Introduction to GIS (1 hour lecture, 1 hour exercises)
- *Definition of terms (IS, GIS, geodata, visualization)*
- *Components of GIS*
- *Introduction to QGIS: Installation and interface overview*

Geodata (2 hours lecture, 1 hour exercises)
- *Data models (vector and raster geodata)*
- *Geodata formats*
- *Creating and editing vector data in QGIS*

Sources of Geodata (1 hour lecture, 2 hour exercises)
- *Geodata standards and exchange*
- *Web map services*
- *Loading geodata into QGIS/WebGIS*

Drawing Maps with GIS (3 hours exercises)
- *Setting up map projects in QGIS/WebGIS*
- *Adding and managing layers*
- *Using QGIS/WebGIS to draw basic maps*

Tabular Data in GIS (1 hours lecture, 2 hours exercises)
- *Linking tabular data with spatial data*
- *Attribute tables and queries*
- *Managing and querying tabular data in QGIS*

Databases in GIS (2 hours lecture, 1 hour exercises)
- *Introduction to databases and their role in GIS*
- *Spatial databases vs. non-spatial databases*
- *Connecting QGIS and WebGIS to spatial databases*

Cartographic Visualization Techniques I (3 hours lecture, 2 hours exercises)
- *Principles of cartographic design*

- *Symbolization and color theory*
- *Labeling and annotation techniques*
- *Applying cartographic principles in QGIS/WebGIS*

Cartographic Visualization Techniques II (2 hours lecture, 2 hours exercises)

- *Advanced visualization techniques*
- *Thematic mapping*
- *Interactive mapping and web-based GIS*
- *Creating thematic maps in QGIS/WebGIS*

Practical Applications of GIS (10 hours lab sessions)

- *GIS in urban planning*
- *GIS in environmental management*
- *Case studies and real-world applications*
- *Implementing practical GIS projects in QGIS/WebGIS*

The homework will include: 20 hrs literature analysis, GIS terminology, and individual study.

Objectives and Competences

Course objectives:

- *To introduce students to Geographic Information Systems (GIS), WebGIS and their components.*
- *To provide an understanding of geodata and data models used in GIS.*
- *To teach the basics of databases and tabular data management in GIS.*
- *To develop skills in drawing maps and applying cartographic visualization techniques.*
- *To provide hands-on experience using QGIS for GIS tasks.*
- *To provide hands-on experience using WebGIS*

Competences:

- *Ability to understand and use GIS components effectively.*
- *Knowledge of different types of geodata and their applications.*
- *Proficiency in managing data models and databases within a GIS framework.*
- *Skills in creating maps and utilizing various cartographic visualization techniques.*
- *Practical experience in using QGIS or WebGIS for GIS operations.*

Intended Learning Outcomes

Students that will successfully attend the course will be able to:

- *Define GIS and describe its key components.*
- *Identify and work with different types of geodata.*
- *Understand and apply data models in GIS.*
- *Manage and use databases and tabular data within GIS.*
- *Create maps using GIS software, specifically QGIS.*
- *Create maps using WebGIS*
- *Apply cartographic visualization techniques to effectively represent spatial data.*

Course Content

Introduction to GIS

GIS Terms

Information system (**IS**), in the computer world, is a system, which consists of people and computers that process or interpret information.

Geographic information system (**GIS**) is a computer-based system to analyse and present spatial data.

Data are facts and statistics collected together for reference or analysis.

Dataset is a collection of related data. Each entry within a dataset typically follows a consistent structure.

Spatial data refers to data which cover more than one spatial dimension (2D, 3D, …).

Geographic data (shortly **geodata**) are data representing features or phenomena related to the Earth.

Metadata are data that describe other data. They provide information about a dataset's content, structure, source, and usage. In the context of geodata, metadata might include details like the data's creation date, the coordinate system used, data accuracy, scale, or descriptions of features.

Cartography is the study and practice of making and using maps. The process of surveying of geographical phenomena and creating a map is known as a **mapping**.

Visualisation is a graphical representation of information, making data easier to understand and interpret. In the context of *data visualisation*, it transforms raw data into charts, graphs, or images to highlight patterns, trends, and relationships. In cartography, visualisation is essential for creating maps that convey geographic data effectively, using symbols, colours, and scales to represent real-world locations and spatial relationships, helping users quickly grasp complex information about places and spatial patterns.

GIS in a Nutshell

A **Geographic Information System** is a system which consists of several components. These components work together to collect, analyse, and interpret spatial data, allowing users to make informed decisions based on geographic information. The key components of a GIS are:

- **Hardware** – physical equipment used to run GIS software, including computers, servers and GPS devices.
- **Software** – GIS applications that process, analyse, and visualise spatial data. Examples include ArcGIS, QGIS, Google Earth Engine etc.
- **Data** – the core of any GIS, including spatial data and attribute data, from sources like satellites, surveys, and databases.
- **People** – the users and experts who manage and analyse data within the GIS, ranging from GIS analysts to decision-makers.
- **Methods** – standardised procedures and models that guide data collection, analysis, and visualisation to ensure consistent, accurate results.

Some also include networks as another component. That means systems for sharing GIS data and applications across teams, such as cloud-based GIS, which enables collaboration and access to real-time data.

Getting Started with GIS Software

GIS software was traditionally only used on **desktop** computers, but recently **mobile GIS** and **web-based GIS** (webGIS) applications are gaining popularity.

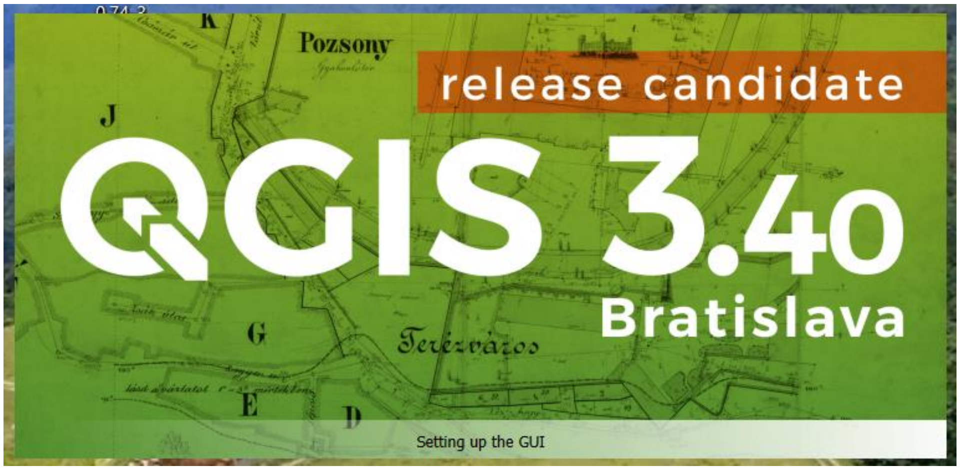
There are five fundamental functionalities of a desktop GIS:

- data input and output,
- visualisation,
- editing,
- analysis and
- map design.

Most desktop GIS tools have these capabilities, although the level of functionality for each of them might differ. Some tools might be more prepared for data editing, while others might focus on analysis.

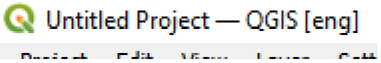
QGIS is a well-established, open-source GIS software. Being open-source software, it is freely accessible to all users.

To start using QGIS, navigate yourself at https://qgis.org/download/ and follow the steps relevant for your operating system. As of November 2024 the latest version was 3.40.



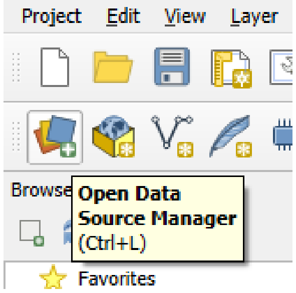
QGIS 3.40 start-up screen.

Once installed, start the QGIS application to investigate its user interface. After the application starts, you can change your locale setting under the “Settings” → “Options…” menu. When you start QGIS for the first time, you shall notice a blank white canvas. That is because there are no geodata to show yet. Work in QGIS is organised into **projects**. A project is a package of all the content in the map canvas and its settings – all layers, their symbology, rendering order, predefined print layouts etc. You know that your new project is not saved yet when you see the “Untitled Project” in the title of the QGIS window. When working on a project in QGIS, like in any other application, it is smart to save your work periodically so you don’t lose all your work in case of an accidental crash. You can save the project via “Project” → “Save” menu.



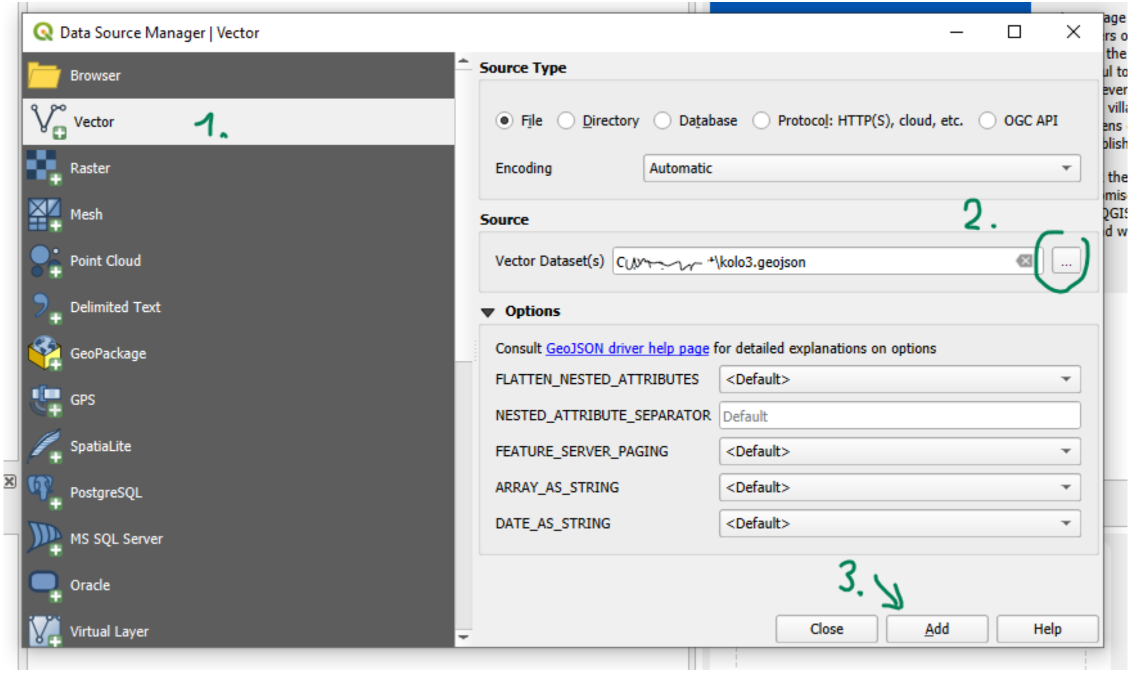
Untitled project is any new project which was not saved yet.

You can add a layer with geographical data into your project in several ways. One of them is to open the “Open Data Source Manager”.



A button to open the “Open Data Source Manager”.

In the manager window, you first select the type of data you are about to open, then the location of the data and finally you can click the “Add” button and add the layer to your new project.



Source Type

● File ○ Directory ○ Database ○ Protocol: HTTP(S), cloud, etc. ○ OGC API

Encoding: Automatic

Source

Vector Dataset(s): C[redacted]\kolo3.geojson

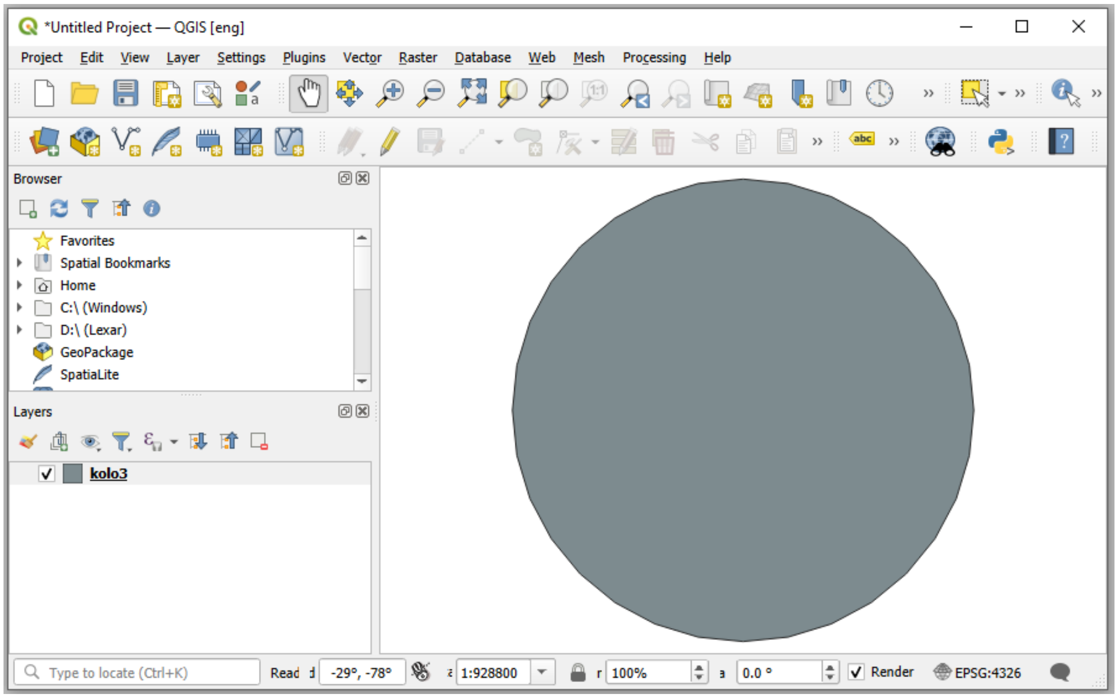
Options

Consult GeoJSON driver help page for detailed explanations on options

FLATTEN_NESTED_ATTRIBUTES: <Default>
NESTED_ATTRIBUTE_SEPARATOR: Default
FEATURE_SERVER_PAGING: <Default>
ARRAY_AS_STRING: <Default>
DATE_AS_STRING: <Default>

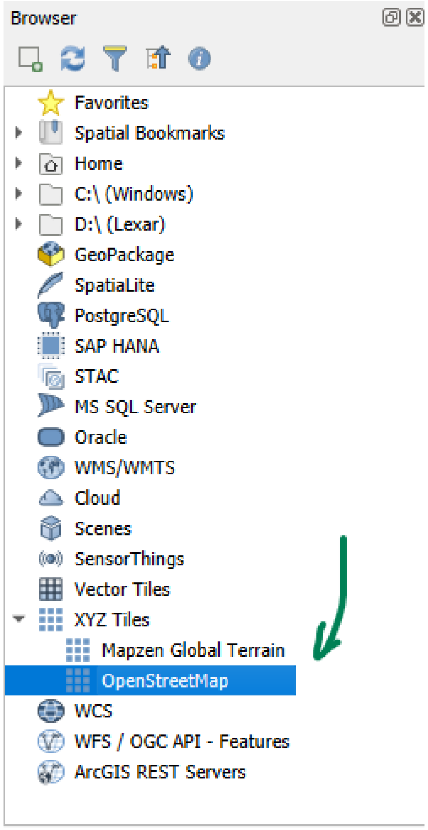
Open Source Data Manager window opening an existing vector layer.

The layer will appear in the “Layers” panel and its content will display in the map canvas.

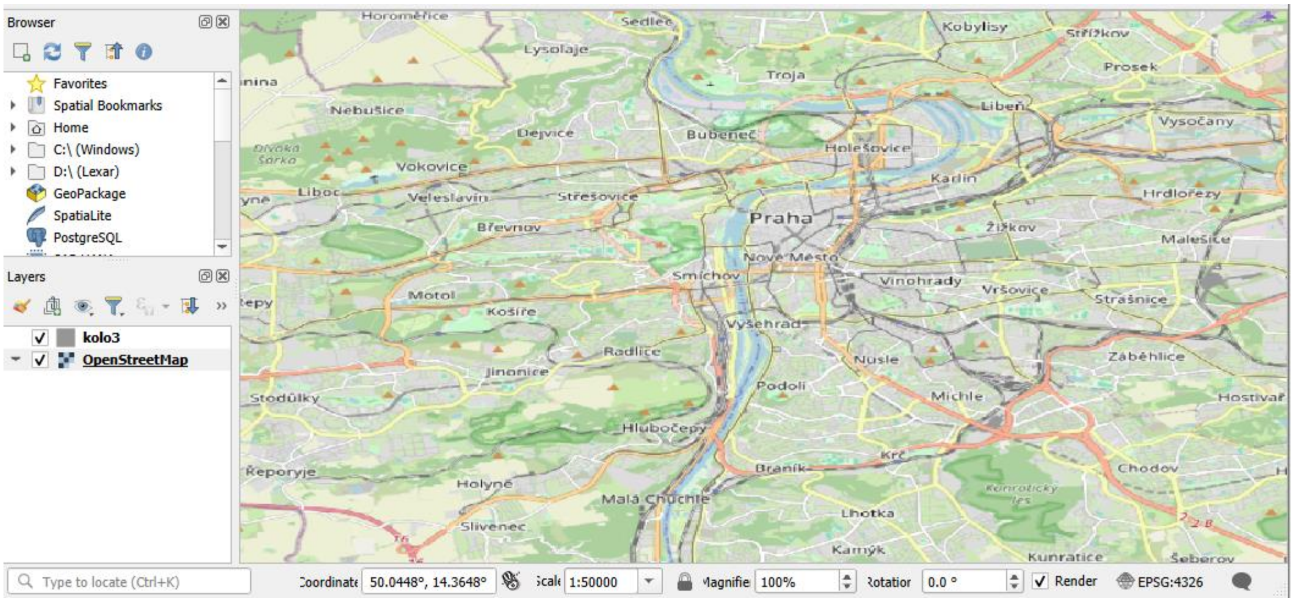


Unsaved QGIS project with one vector layer "kolo3". There is only one feature in the layer, which is a circle (shown in grey).

Another option is to browse for layers in the "Browser" panel on the left side. Some external base layers can be also added quite quickly if you find the "XYZ Tiles" category and double click one of "OpenStreetMap" or "Mapzen Global Terrain" layers. The layer is immediately added to the Layers panel and in the map canvas. If you feel like the map is skewed or distorted in another way, this is due to the selected spatial reference system. You can learn more about various spatial reference systems and their properties in the course "Mapping fundamentals".



Adding an OpenStreetMap basemap from the browser window.



Coordinate 50.0448°, 14.3648° Scale 1:50000 Magnifier 100% Rotation 0.0 ° ☑ Render EPSG:4326

OpenStreetMap layer centred on Prague and zoomed to scale 1 : 50 000 in WGS84 spatial reference system. Layer "kolo3" is not in a visible extent now.

You can navigate in the map canvas with your mouse. Use panning to move the map and scroll the wheel to zoom in or out. More detailed overview of the QGIS interface can be found in the Lesson 2.1 of the QGIS Training Manual.

Relevant online sources to start with QGIS:

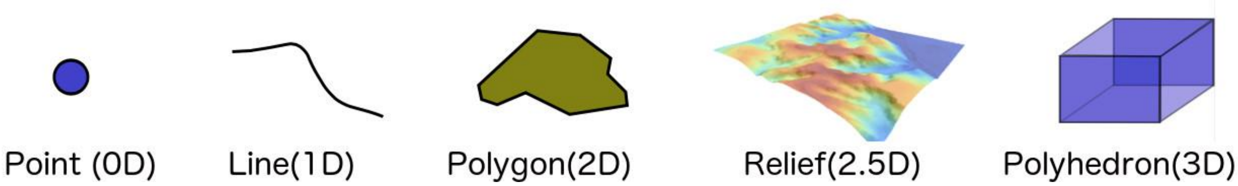
- QGIS Training Manual: https://docs.qgis.org/latest/en/docs/training_manual/index.html
- QGIS Tutorials: https://www.qgistutorials.com/en/

Geodata

About Geodata

Geodata are the lifeblood of GIS; without it, GIS has nothing to process, analyse, or visualise. Geodata itself carry two types of information: **spatial** and **thematic**. The spatial information contains the position, referred to a given reference system, and it answers the question “*where?*”. The thematic information answers the question “*what?*” and it defines the characteristics of the phenomenon or feature that occurs at the location indicated by the spatial component.

An important concept to consider related to geographical information is the **dimension**. The elements that we store range from simple points (0D), to three-dimensional volumes (3D)



Geodata with different dimensions as commonly represented in GIS. Source: OLAYA, Víctor. Introduction to GIS. 2018, CC-BY.

In a GIS, the information about a given study area is divided into several levels. Even if it refers to the same location, the information about different phenomena is stored separately. That is, a set of different blocks of information exists for the same area, each of them containing a particular variable or set of elements. Each of these blocks is called a **layer**. The concept of layer is fundamental to understand GIS and helps to correctly structure and manage geographical information. All the geodata that you will use in a GIS will be in the form of layers. Each one of them can be used independently or together with others.

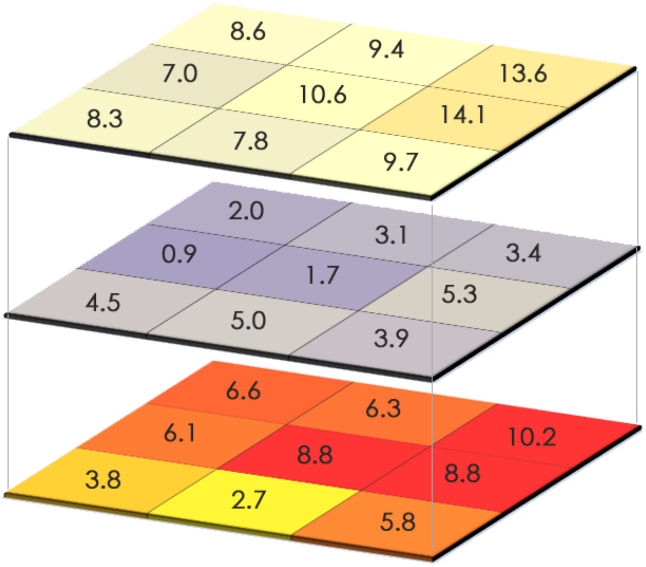
The main feature of a GIS to transparently integrate data corresponding to different areas and create a seamless mosaic is the separation between the data and its **visualisation**. Data is required for visualisation, but these two perspectives constitute different parts of a GIS, with a clear separation between them. That means that data is used to create a visual output, but data itself does not contain any value related to its rendering and visualisation. Thus, it is possible to combine data and then represent that combination together as a whole.

Geodata Models

Geodata in GIS can be represented in various models. A representation model is a way of coding the concept into a finite set of elements. Two main representation models are the raster model and the vector model. Layers using these models are commonly known as **raster layers** and **vector layers**.

The most common **raster model** is based on a grid of square cells, often called pixels. Generally, pixels can carry any type of information, but most commonly its value is a numeric value or a set of numeric values. If the values are numerical, the raster layer can be seen as a matrix and the corresponding mathematical tools can be used for its analysis. The number of values stored in each pixel defines the number of *bands* of that raster layer. Images taken with a digital camera are a great example. In a colour image, each pixel carries three values: those for red, green and blue colour. Hence, an image like that has three bands. An image can sometimes be converted into a greyscale image, in that case, it would have only one band, and the value would represent the saturation of grey (from white to black). Another typical use of the raster model is for the Digital Elevation Models (DEM), which describe the topography of a certain area. DEMs are always single band layers.

Raster model is also suitable to represent objects in three dimensions. A 3D cell, an analogy to a pixel in 2D, is a cube cell, sometimes called voxel.

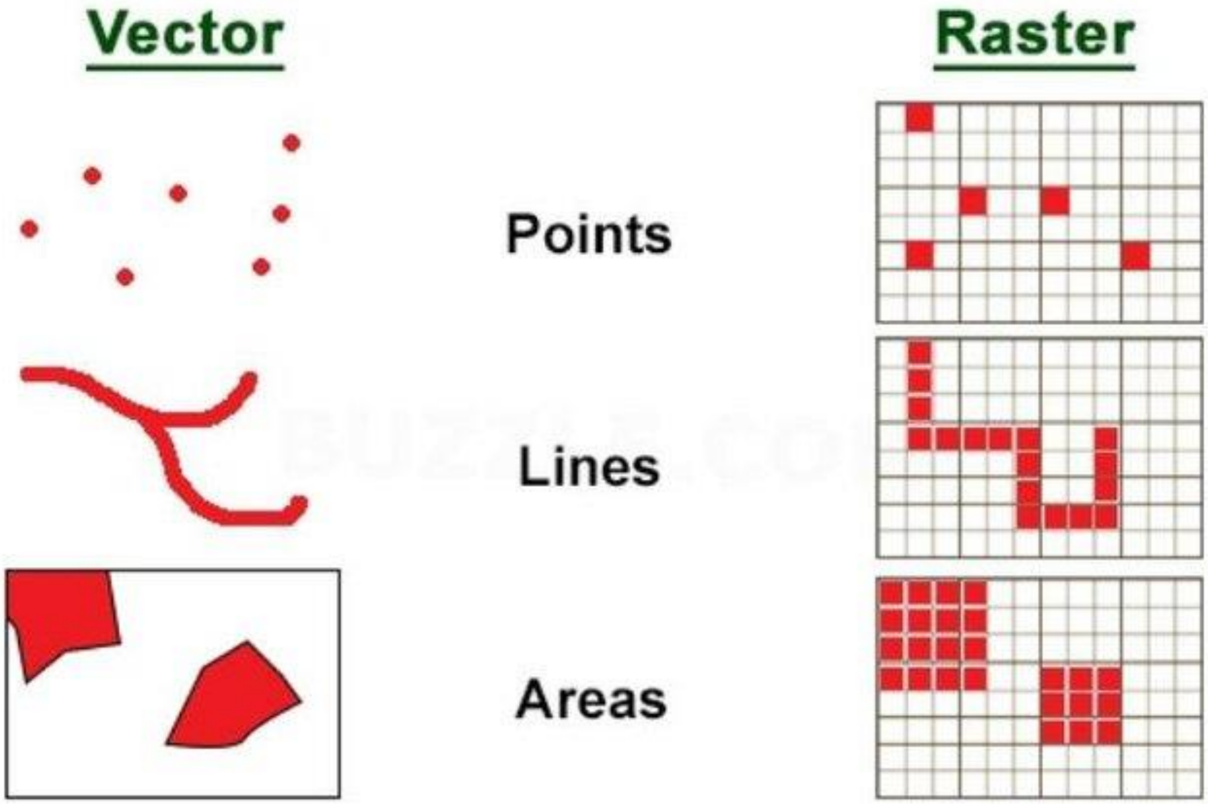


An illustration of a raster layer with 3x3 pixels (9 cells) and three bands. Source: GIS Geography, https://gisgeography.com/spatial-data-types-vector-raster .

In the **vector model**, there are no fundamental units like cells that divide and cover the modelled area. Instead, the geometry and characteristics of the described elements is modelled using *features*. Features carry two kinds of information:

- geometry, which is the spatial information, and
- attributes, which is the thematic information.

A layer usually contains multiple attributes. Attributes are associated with features, can have information of all types and they are more versatile than the values associated with raster layers, which normally contain just numerical values. Due to its particular structure (a set of attributes associated with a feature), the thematic component in the vector model can be represented as a *table* and stored in a *database*. Also, it can be analysed independently of the spatial component.



Comparison of features with different geometries represented in both vector and raster models. Source: Polat, Zeynel & Alkan, Mehmet. (2019). Design and Develop GIS for Regional and Urban Planning.

Both the raster and vector representation models can be used to store any geographical information. Digital elevation models (DEMs) are a typical case of raster layers. Representing elevation as a raster layer has many advantages, especially for performing analysis, but it is not the only option. We can have a vector layer with points (that will be the case if the elevation data comes for a topographic survey), or a lines layer with contour lines (the most common way of representing elevation in a traditional map). Overall, there is **no representation model that is better than the other**. Depending on the case, one will be more suitable than the other.

In general, it is better to use raster layers for continuous variables such as elevation, in order to make it easier to perform analysis based on them. Discrete variables, on the other hand, are better represented using a vector approach.

There are algorithms that allow converting between the raster and vector representation models, so if we have our data in one of them, we can obtain a new layer that uses the other model and might be more suitable for our work.

Geodata Formats

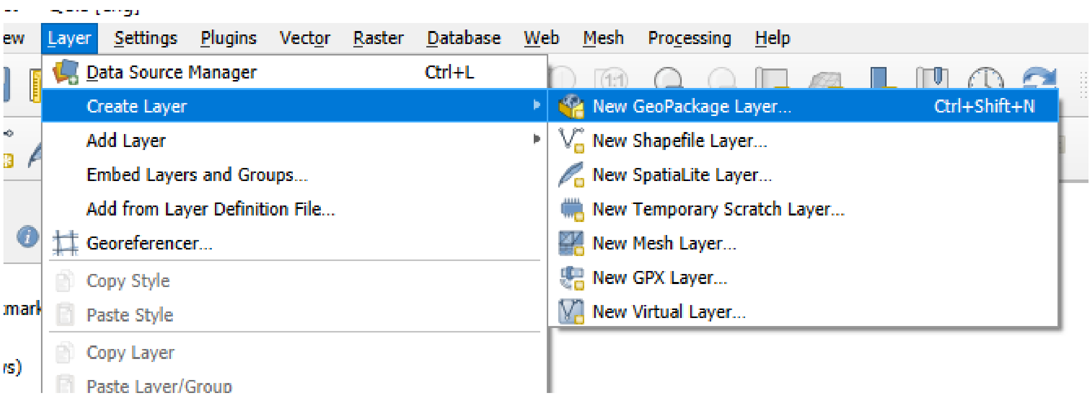
Both raster and vector data can be stored in various formats, which differ in their internal structure, readability, capabilities, size and interoperability. Some widely used formats used for geodata are:

- **GeoJSON** (vector): A lightweight JSON-based format for storing simple geographical features, commonly used for web mapping applications.

- **Shapefile** (vector): An older, widely-used ESRI format that stores geographic features as separate files (e.g., .shp, .shx, .dbf) but lacks support for advanced data types and metadata.
- **GeoPackage** (vector and raster): A modern, single-file SQLite-based format that supports complex geodata and attributes, designed for efficient data storage and mobile use.
- **KML** (vector): An XML-based format used mainly for displaying geographic data in Google Earth, focusing on presentation rather than complex data types.
- **GML** (vector): A versatile XML-based format that supports complex geographic features, often used in interoperability for diverse GIS systems.
- **GPX** (vector): A format primarily for GPS data, storing waypoints, tracks and routes, optimised for navigation devices.
- **TIF** (raster): A high-quality raster format supporting georeferencing (GeoTIFF), commonly used for satellite imagery and detailed maps.
- **JPG** (raster): A widely-used compressed image format without native georeferencing, often used for simple visual maps but not for analytical GIS work.
- **TXT** (vector or raster): A basic text format that can contain geographic coordinates or attribute data in a simple, unstructured form, often used for quick data sharing.
- **CSV** (vector or raster): A plain-text format that stores data in a table structure, commonly used for attribute data and simple geographic coordinates (like latitude and longitude), but lacks built-in support for complex geospatial structures or metadata.

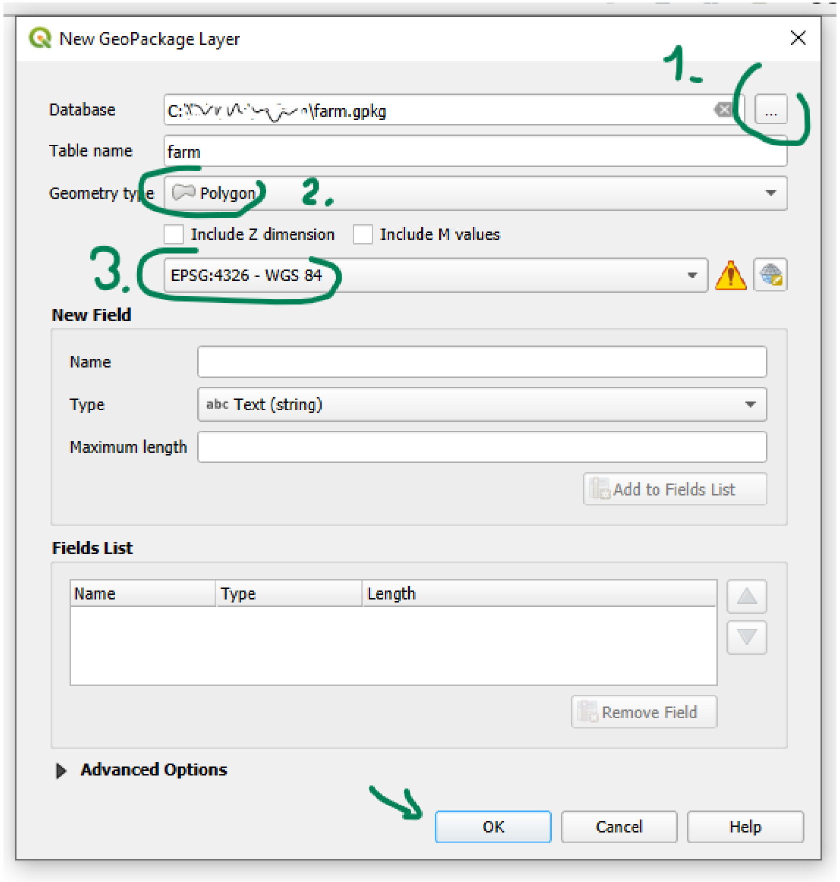
Creating and Editing Vector Data in QGIS

Creating a new vector layer in QGIS is straightforward. In the menu under “Layer” select “**Create Layer**”. From the options given there, choose a proper format for the layer to be created. If uncertain, use Geopackage, which is suitable in most of the cases. Temporary Scratch Layer can be also useful if you want to experiment. Temporary Scratch Layer is deleted once you close QGIS, but it can be made permanent (saved to the drive), if necessary.



The menu in QGIS for creating a new vector layer.

If you are creating a new permanent layer (Geopackage, Shapefile, etc.) you have to specify a location in which you like to store the geodata. Then you should select a **geometry of features** you want to create in this layer. Traditionally, one layer only contains one type of geometry for all features. You must also specify a spatial reference system in which the geometry will be represented. WGS84 is a world-wide acceptable option, but as it is a geographic coordinate system, it has its limits in accuracy and in the calculation of areas or volumes. A local projected spatial reference system must be selected if a higher precision of coordinates is needed. In this step you can also specify which attributes, here called fields, the new layer will carry. You can skip that now, as new attribute columns can be added later.



Database: C:\[redacted]\farm.gpkg

Table name: farm

Geometry type: Polygon

☐ Include Z dimension ☐ Include M values

EPSG:4326 - WGS 84

Name:

Type: abc Text (string)

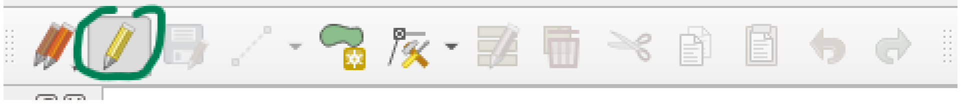
Maximum length:

Name	Type	Length

Creating a new vector layer in Geopackage format in QGIS.

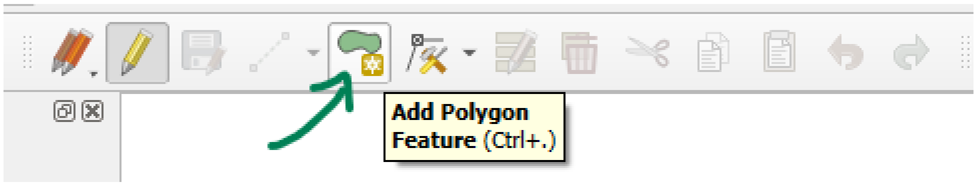
If you intend to add new features based on some other layer like a basemap or satellite imagery, add the appropriate layer(s) now. A process of redrawing features into a vector layer from a raster layer is called a **vectorisation**.

A newly created layer contains no features. To add some features to the layer, you first have to toggle into an edit mode by clicking a pencil icon in the upper toolbar. In the edit mode, you can add new features, modify or delete existing ones. Only one layer can be edited at a time and it will be the one, which is selected (highlighted) in the Layers panel.

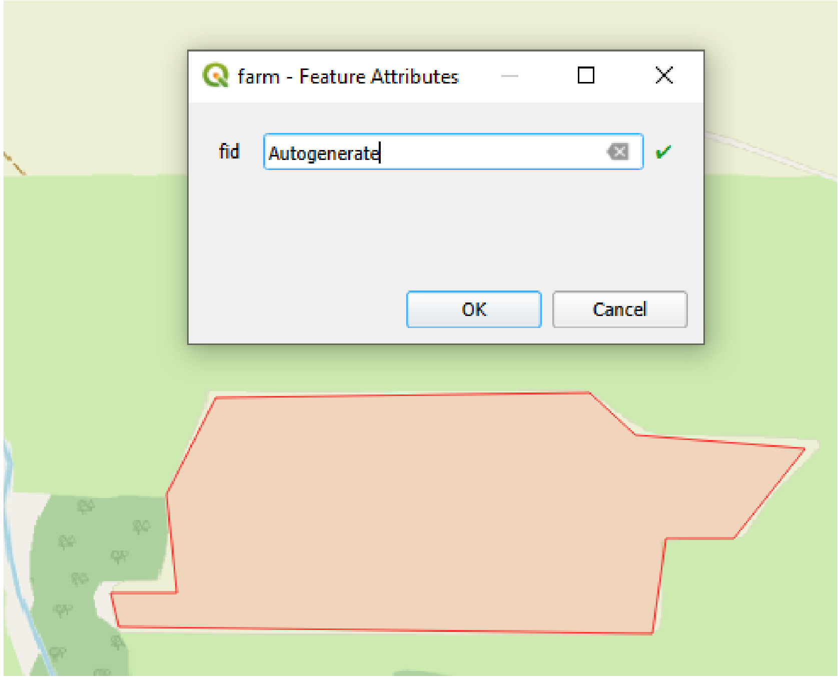


Toggle edit mode button in the toolbar, which is enabled at the moment.

Once the edit mode is enabled, some new buttons are allowed in the same toolbar. One of them allows you to draw new features on the canvas. It is only possible to draw features with the geometry specified when the layer was created.



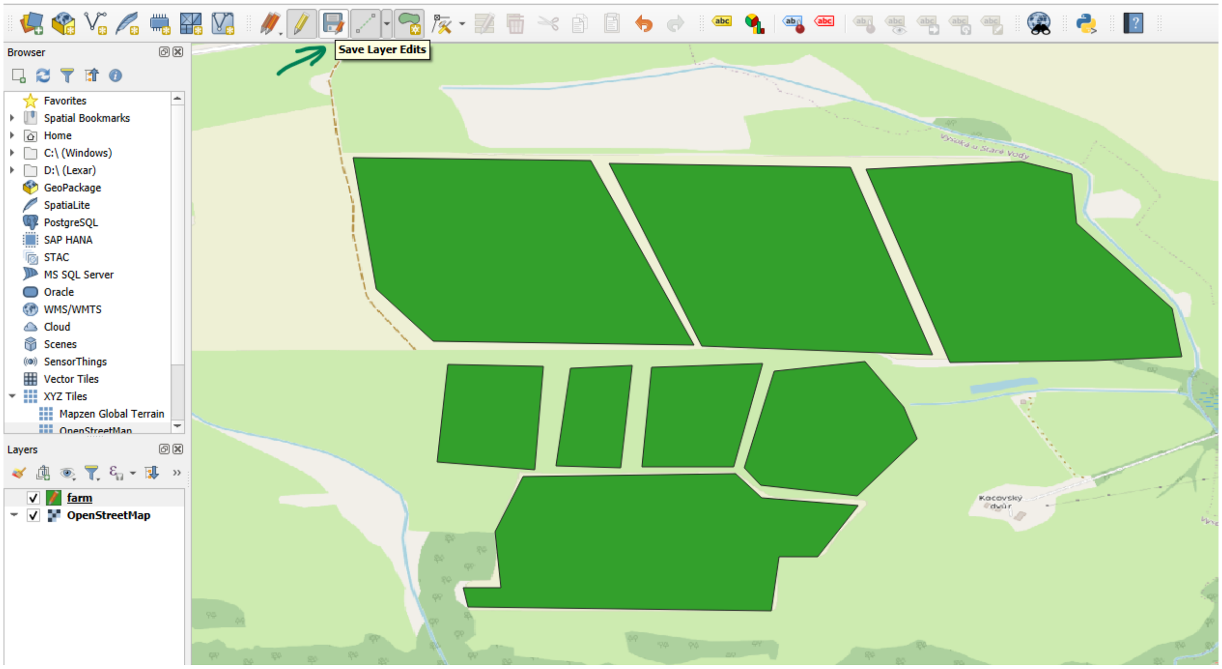
To draw a new polygon into your layer, zoom closer to your basemap and click on the locations in the map to draw a boundary of the desired polygon. The drawing is finished by right-clicking the mouse. QGIS then asks to enter an **ID for the new feature** (fid = feature ID). That is because every feature must have its unique identifier in the attribute table. If you leave the value "*Autogenerate*", QGIS will assign trivial unique IDs to your new features once you save your edits.


farm - Feature Attributes

fid: Autogenerate

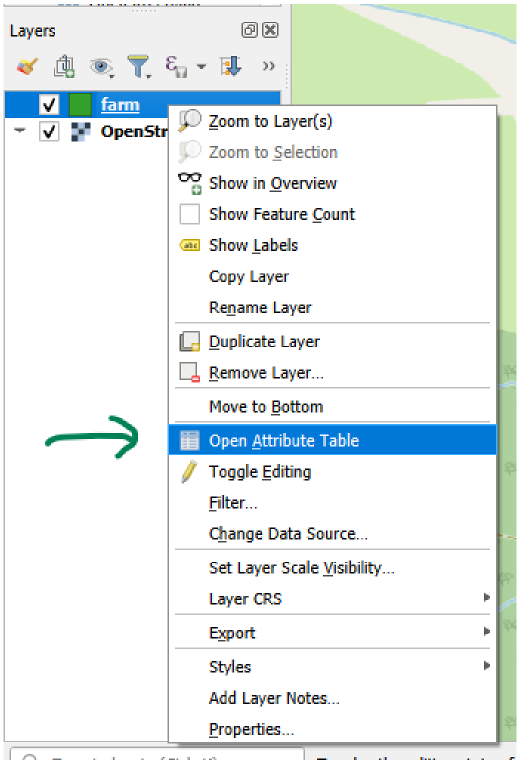
New feature created representing a field. Its ID will be assigned automatically when the edits are saved.

When you draw new features, they are not yet stored in your layer and are only temporary elements. To make your edits permanent, you have to click the diskette button in the editing toolbar. It will save your changes (additions, modifications or deletions) to the layer being edited. After saving your changes, you can either continue editing or you can toggle the edit mode again, if you have finished.



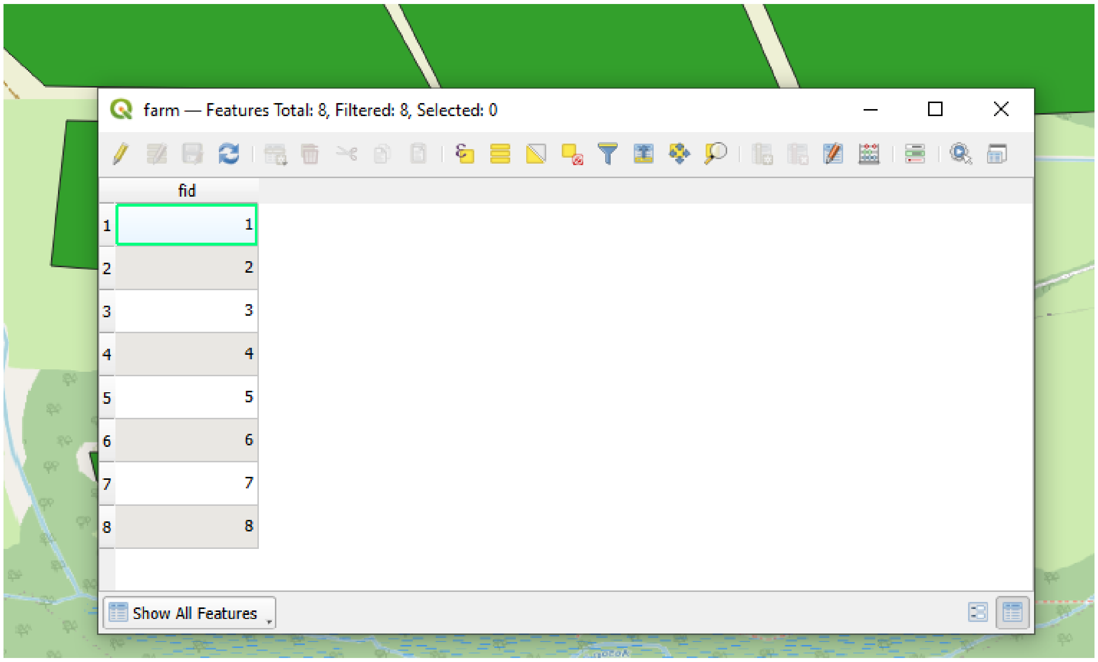
Several fields vectorised in the layer "farm" and displayed in the dark green colour above the OpenStreetMap basemap.

One of the very common operations in GIS when working with layers is to browse through the layer's attributes. Attributes in GIS are displayed usually in an **attribute table**. This table represents each feature as one row in a table (also called a "record") and the feature's attributes in individual columns. Attribute tables are usually only available for vector layers, but QGIS also supports attaching an attribute table to raster data via a sidecar-file VAT.TBF.



Opening an attribute table of a vector layer.

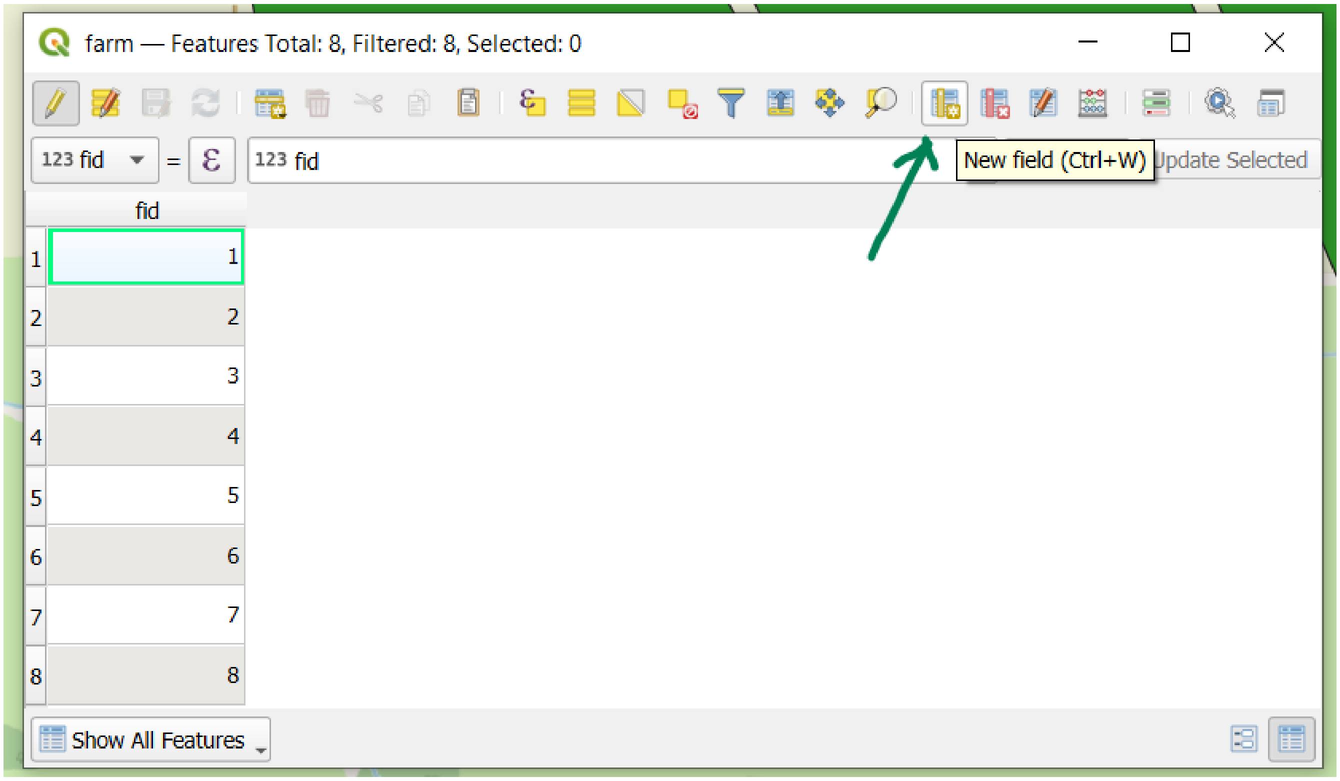
Attribute table gives you an option to browse through the attributes and see their values. You can also edit the attributes or make **selections** of the data. To edit values, add or delete columns or rows (features), you must again toggle into an edit mode. This is to prevent any accidental changes to your data.


farm — Features Total: 8, Filtered: 8, Selected: 0

	fid
1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	8

Attribute table for the newly vectorised layer is not very content rich. It only contains feature IDs.

Once you enter an edit mode you can add a new column into the attribute table by clicking the “New field” button.

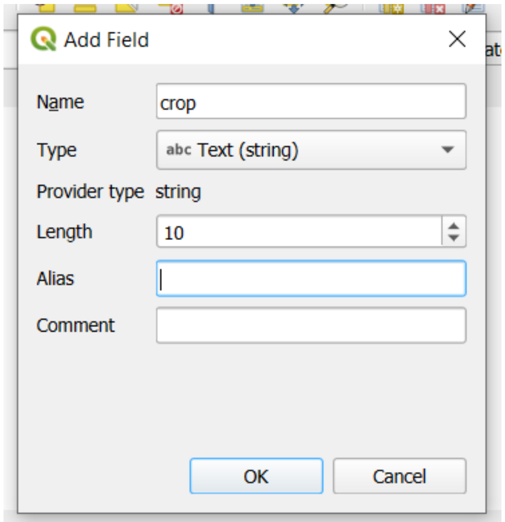


farm — Features Total: 8, Filtered: 8, Selected: 0

	fid
1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	8

Attribute table in edit mode with “New field” button enabled.

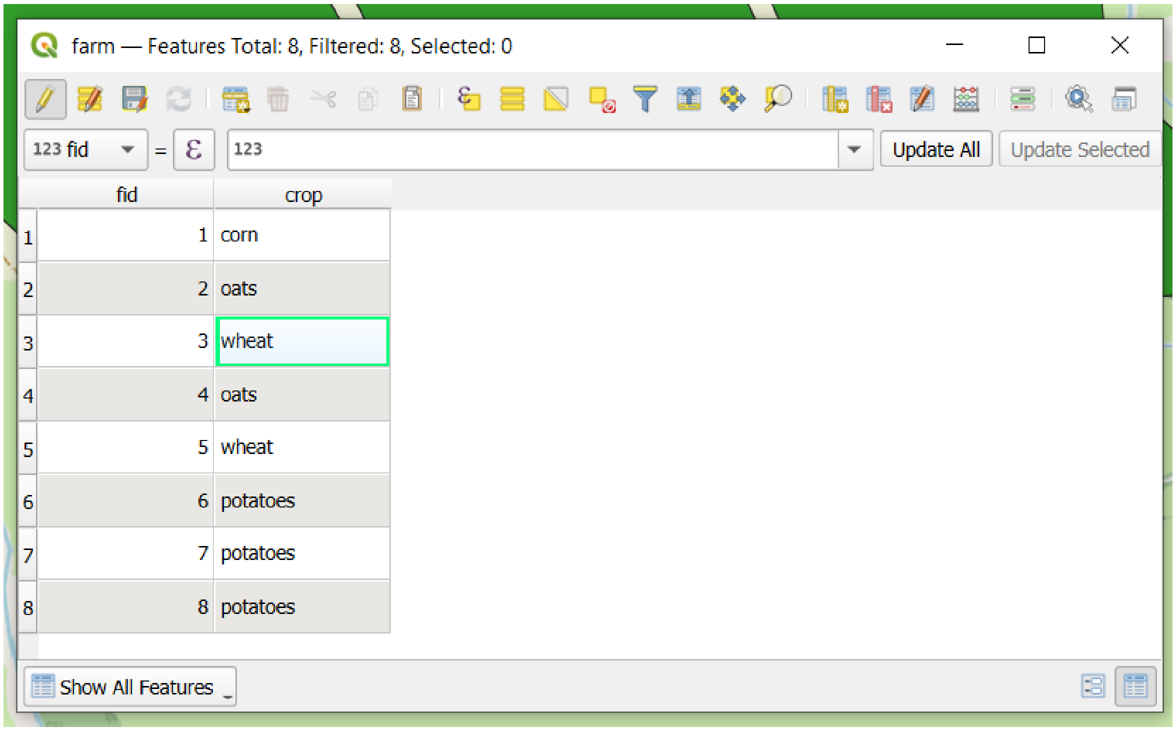
When adding a new field, you must specify its name and its data type. Choose type “Text (string)” for textual data like descriptions, names or categories. Text data type must also be set with a maximum length the text can have. This is not possible to change later, so set the length with regard to expected values you will fill in the attribute. “Decimal number (real)” type is suitable to hold numeric values of any form including decimals, e.g. area, soil pH or average rainfall. “Integer (32 bit)” and “Integer (64 bit)” data types might be useful for numeric values which take integer values only, e.g. population, postal code or livestock count.



Name: crop
Type: abc Text (string)
Provider type: string
Length: 10
Alias:
Comment:

Adding a field for text attribute to specify a crop type.

When a new field is added, it is initiated with a value “**NULL**”. “NULL” is a special reserved value and means “no value” or “no data”. You can fill in the values by simply typing the desired values into the cells (provided you are still in edit mode). Once you are finished editing the attributes you must save your edits just like in the case of drawing / editing geometries. Then you can leave the edit mode.



	fid	crop
1	1	corn
2	2	oats
3	3	wheat
4	4	oats
5	5	wheat
6	6	potatoes
7	7	potatoes
8	8	potatoes

Attribute table for the vector layer “farm” with a “crop” attribute filled with values of a crop type. Each row represents one field in a farm.

Relevant online sources to start working with QGIS:

- QGIS Training Manual: https://docs.qgis.org/latest/en/docs/training_manual/index.html
- QGIS Tutorials: https://www.qgistutorials.com/en/

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Sources of Geodata

Geodata Standards and Exchange

The most common standards for geographical information are created and promoted by the **Open Geospatial Consortium** (OGC). The OGC is “an international not-for-profit organisation committed to making quality open
standards for the global geospatial community”. Some of the most relevant OGC standards are the following ones:

- **GML**. XML-based standard to store geographical information.
- **Geopackage**. Portable geospatial data format that stores vector data, raster data and their associated attributes in a single SQLite database file.
- **KML**. XML-based format, supporting 3D visualisations and simple map annotations.
- **3D Tiles**. A standard for streaming massive 3D geospatial datasets like city models or terrain to web and mobile devices.
- **Sensor Things API**. Standard for efficient collection, sharing, and querying of Internet of Things (IoT) sensor data, including observations and their spatial and temporal context.
- **GeoSPARQL**. Standard that extends the SPARQL query language to support the representation, querying, and reasoning of geospatial data on the Semantic Web.
- **Filter Encoding (FE)**. Defines a standardised way to express spatial and non-spatial queries for use in OGC services like WFS or WMS.
- Web map services standards **WMS**, **WMTS**, **WFS**, **WPS**, **CSW** – see below.

Each one of these standards is described in the corresponding specification, which is subject to change and improvement. Several versions exist for each of them. Along with these standards are those made by organisations such as ISO or W3C, with a more general scope, but also important in the context of GIS. Among them, the most relevant standards are the ISO ones that define how to store **metadata** and the W3C standards related to communication over the Internet. Most relevant ISO metadata standards are:

- **ISO 19115**: Focused on describing geographic information and services, providing a framework for metadata that helps catalogue, discover, and manage geospatial data.
- **ISO 19139**: Defines XML schema for the implementation of metadata according to ISO 19115, making it machine-readable.
- **ISO 19157**: Specifies principles for evaluating and reporting the quality of geographic data, often used in metadata quality assessment.

There are also W3C standards for metadata, which are relevant in the GIS industry:

- **Dublin Core (DCMI)**: A widely used standard for general-purpose metadata, defining 15 core elements such as "Title," "Creator," and "Date."
- **RDF (Resource Description Framework)**: A framework for representing metadata as linked data, often used to create semantic relationships between datasets.
- **SKOS (Simple Knowledge Organization System)**: Used for managing and linking controlled vocabularies, taxonomies, and metadata classifications.

A **Shapefile** is a popular geospatial vector data format created by Esri and primarily used in their software. While widely used in GIS, it is not an OGC standard. It stores geometric data (points, lines, polygons) and associated attributes in separate files.

Web Map Services

Web map services are server-based systems that provide geospatial data and maps over the internet. These services allow users to access, view, and interact with geographic data through a web browser or GIS software without needing to download the full dataset. The data is delivered as map images (e.g., PNG, JPEG) or, in some cases, as raw vector or raster data for advanced analysis. By adhering to these standards, web map services enable seamless integration of geospatial data into diverse applications, from environmental monitoring to urban planning and disaster management.

The **OGC Web Service Common (OWS)** serves as a base standard for web mapping. It defines the shared protocols and behaviours that underpin WMS, WFS, WMTS, and other related services, ensuring interoperability and consistency across implementations. This standard includes:

- **Request/Response Structures**: Defines how clients and servers exchange data.
- **Service Metadata**: Ensures consistent descriptions of services (e.g. capabilities documents).
- **Error Handling**: Specifies standard error formats for interoperability.

Several OGC standards define individual web map services:

- **WMS (Web Map Service)**. To serve maps as images. It defines a protocol for delivering georeferenced map images over the internet. It allows users to request maps in various formats (e.g. PNG, JPEG) and styles, based on specific parameters like geographic extent, layers, and coordinate reference systems. WMS is widely used for visualising geospatial data without transferring the underlying dataset.
- **WMTS (Web Map Tile Service)**. To serve maps as images in preprocessed tiles. It provides fast and efficient delivery of map tiles by pre-rendering and storing fixed, tiled images at various zoom levels. It is optimised for web and mobile applications, ensuring quick map visualisation by dividing maps into manageable, pre-defined image tiles
- **WFS (Web Feature Service)**. To serve geographical features (vector layers). It enables the retrieval of vector data over the web, allowing users to request actual geographic data in formats like GML. Unlike WMS, which serves raster map images, WFS provides access to raw data, enabling spatial analysis, querying, and manipulation of individual features. The **WFS-T** (Transactional Web Feature Service) extension adds capabilities for users to also update, add and delete features on the server, supporting editing and transactional workflows. This makes WFS and WFS-T ideal for applications requiring dynamic geospatial data management and real-time collaboration, such as in urban planning and field data collection.
- **WPS (Web Processing Service)**. To serve remote processing services.It allows users to perform spatial analysis and geoprocessing tasks over the web by submitting processing requests to a server. It enables the execution of complex geospatial operations, such as buffering, reclassification or raster calculations and returns the processed results in a standard format.
- **CSW (Catalogue Service for the Web)**. To make queries to a catalogue that contains geographical data. It enables the discovery, querying, and management of metadata about geospatial datasets and services over the web. It allows users to search for available geospatial resources based on criteria like keywords, geographic location or temporal coverage.

A popular **ArcGIS Server** software partially complies with OGC standards, offering support for some key services like WMS (Web Map Service), WFS (Web Feature Service), and WCS (Web Coverage Service). However, due to its proprietary nature, some ArcGIS Server services are extended beyond the OGC standards, incorporating additional features that may not be fully aligned with OGC specifications, especially for more complex workflows and data formats.

Loading geodata into GIS

In QGIS, the **Data Source Manager** is the ultimate place where you can connect to various types of geodata. Types of geodata supported in version 2.40 are:

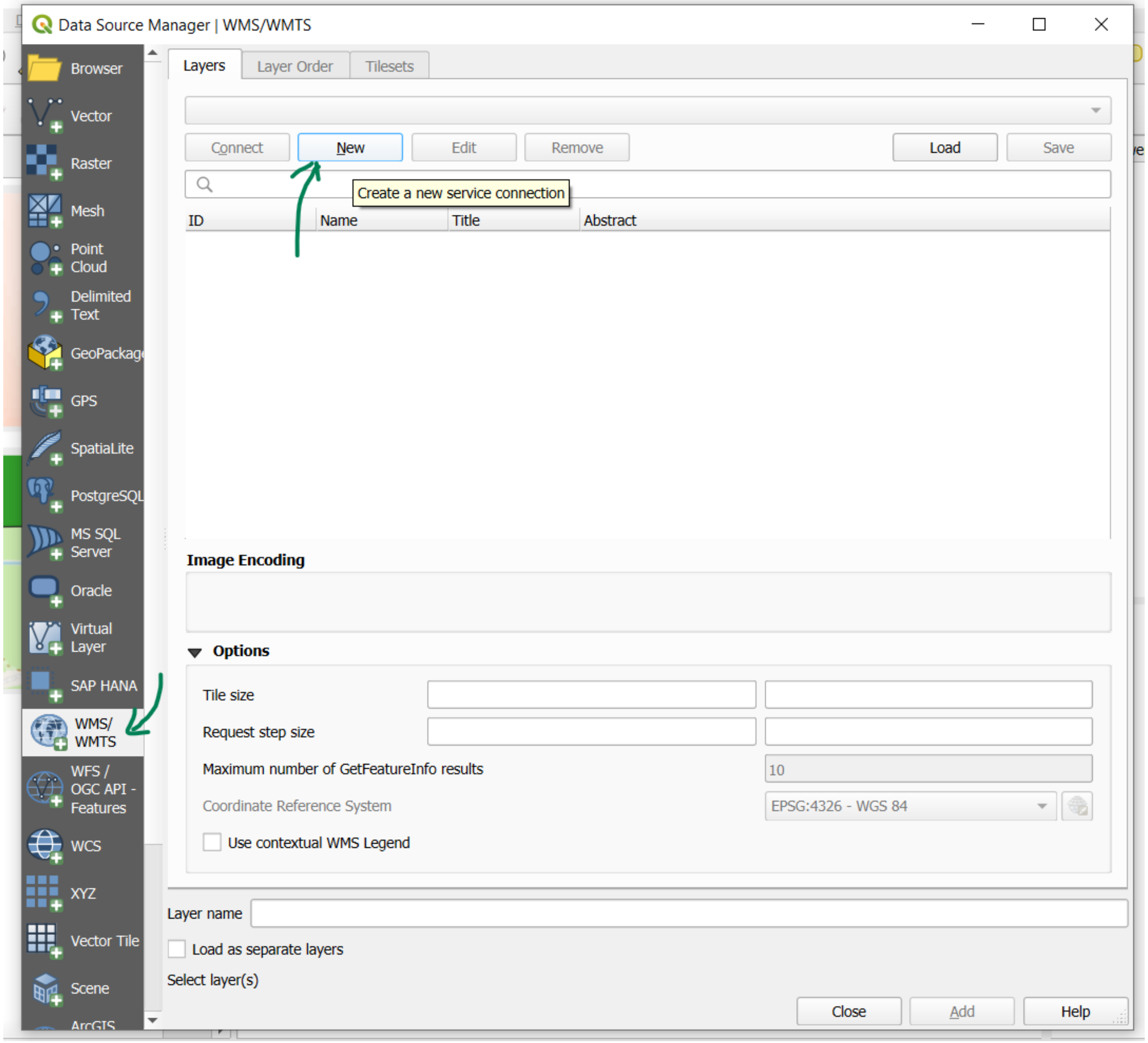
- **Vector data** – Common file extensions include .shp, .geojson, and .gpx. Usually representing discrete features such as roads, boundaries or land parcels
- **Raster data** – Common file extensions include .tif, .jpg, and .png, typically used for continuous data such as satellite imagery, elevation models or land cover classification.
- **Mesh** – Represents 3D surfaces using interconnected nodes (vertices) and edges, forming a network of triangles or polygons to model complex geometries like terrain or buildings. It is typically used for high-resolution modelling of surfaces and is associated with file extensions such as .ply, .tin, or .adf.
- **Point Cloud** – Point cloud data consists of a large collection of individual points in 3D space, often captured by laser scanners (LiDAR) or photogrammetry, representing surfaces and objects in high detail. Common file extensions include .las (LASer file format), .laz (compressed LAS), and .xyz (XYZ text format), typically used in applications like topography, infrastructure modelling, and environmental monitoring.
- **Delimited Text** – Delimited text data stores spatial information in plain text format, with coordinates and attributes separated by a specific delimiter (e.g. commas, tabs). Common file extensions include .csv (Comma-Separated Values), .txt (Text), and .tsv (Tab-Separated Values).
- **Geopackage** – Open, standards-based and container format for storing both vector and raster data in a single SQLite database file. The file extension is .gpkg.
- **GPS** – GPS data refers to coordinates collected from GPS devices, representing locations on Earth in latitude, longitude and sometimes elevation. The common file extension for GPS data is .gpx (GPS Exchange Format). This format is used to store waypoints, tracks and routes, commonly for navigation, outdoor activities and mapping purposes.
- **SpatiaLite** – SpatiaLite is an extension to SQLite that enables the storage and management of spatial data within a lightweight, file-based database. The file extension is .sqlite or .db, and it supports both vector and raster data, along with spatial indexing and geospatial queries.
- **PostgreSQL** – PostgreSQL is an open-source relational database management system that, with the PostGIS extension, supports the storage and querying of spatial data. It is used to store large-scale vector and raster datasets with advanced spatial indexing and geospatial operations. The format does not have a specific file extension, as it is a server-based system.
- **MS SQL Server** – MS SQL Server is a relational database management system that, with the Spatial Data extension, supports the storage and querying of spatial data. The format does not have a specific file extension, as it is a server-based system.
- **Oracle** – Oracle Spatial is an extension of the Oracle Database that enables the storage, management, and analysis of spatial data. It supports both vector and raster data, offering powerful spatial indexing, geospatial functions, and advanced querying capabilities. As a server-based system, it does not have a specific file extension.
- **Virtual Layer** – A Virtual Layer in GIS is a layer that represents data derived from a query or a combination of multiple data sources, without physically storing the data itself. It is typically

used to perform complex queries or operations on data from various formats, like Shapefiles, PostGIS, or SpatiaLite, without the need to import or replicate the data. Virtual layers in QGIS are defined using SQL queries, and they do not have a specific file extension since they are dynamically generated based on the query results.

- **SAP HANA** – SAP HANA is an in-memory, column-oriented relational database management system that supports spatial data through its SAP HANA Spatial extension. It allows for the storage and analysis of both vector and raster data, offering advanced spatial indexing and geospatial queries. As a server-based system, it does not have a specific file extension.
- **WMS/WMTS** – WMS delivers maps as static images (typically in formats like PNG or JPEG) generated from spatial data, while WMTS serves maps as tiled images that allow for more efficient navigation and zooming. These services do not store spatial data directly but provide access to it via web requests. Both formats rely on standard web protocols (HTTP, XML) for data delivery.
- **WFS / OGC API - Features** – Serving vector data over the web, allowing users to request, query, and interact with geospatial features. WFS provides access to raw geographic features in formats like GML or GeoJSON, while the newer OGC API - Features offers more modern RESTful access to spatial data, with JSON or GeoJSON as common output formats. Both standards allow for spatial queries and can support editing or updating features in some configurations.
- **WCS** – WCS is a standard for serving raster data over the web, allowing users to request grid-based data (such as satellite imagery, elevation models, or temperature maps) in formats like GeoTIFF or NetCDF. Unlike WMS, which provides static image maps, WCS delivers the actual data (as raw pixels or values), enabling users to perform further analysis or processing on the raster data. It supports spatial queries and can return data in different coordinate reference systems.
- **XYZ** – The XYZ format refers to a simple tile-based system for serving map data, commonly used for web mapping services. In this format, map data is divided into square tiles (typically 256x256 pixels) at various zoom levels, and the tiles are indexed using a coordinate system based on X (longitude), Y (latitude), and Z (zoom level). XYZ tiles are often used in web mapping platforms like OpenStreetMap or Google Maps, where tiles are dynamically requested from a server as the user zooms or pans the map.
- **Vector Tile** – Vector tiles are a format for serving map data as vector graphics, rather than raster images, which allows for more flexibility and interactivity in web maps. The map data is divided into tiles at various zoom levels, but instead of pixels, the tiles contain geometries (points, lines, polygons) and attributes, usually in formats like PBF (Protocol Buffers). Vector tiles enable client-side rendering, making maps more responsive and customizable, and are commonly used in applications like Mapbox or in services that require high-performance mapping.
- **Scene** – A scene refers to a 3D representation of a geographic area, typically used for visualising spatial data in a three-dimensional environment. Scenes combine various types of data, such as terrain, buildings and other features, to provide a realistic view of a landscape or urban area. In modern applications, scenes are often supported as Cesium 3D Tiles files (such as tileset.json) or through server connections to Cesium 3D Tiles or Quantized Mesh, allowing for the efficient streaming and visualisation of large-scale 3D data.
- **ArcGIS REST Server** – An ArcGIS REST Server is a web service provided by Esri's ArcGIS Server that allows users to access and interact with GIS resources via RESTful APIs. It supports both vector and raster data, enabling functionalities like querying, editing and analysing geographic information through web requests. The service can expose layers, maps, geoprocessing tools and spatial analysis functions, making it ideal for integrating GIS capabilities into web applications.

- **Sensor Things** – Provides a RESTful interface to interact with data from IoT (Internet of Things) sensors, including environmental data like temperature, humidity, and air quality, and spatial information such as location and time. The API allows for querying and managing sensor data, with responses typically in JSON format, enabling seamless integration of sensor data into GIS applications and real-time monitoring systems.

In **QGIS**, the process of connection to a WMS/WMTS, WFS or WCS server is similar. First, you must specify a connection to the server. If you have not yet specified any connection before, click "New".



Maximum number of GetFeatureInfo results: 10

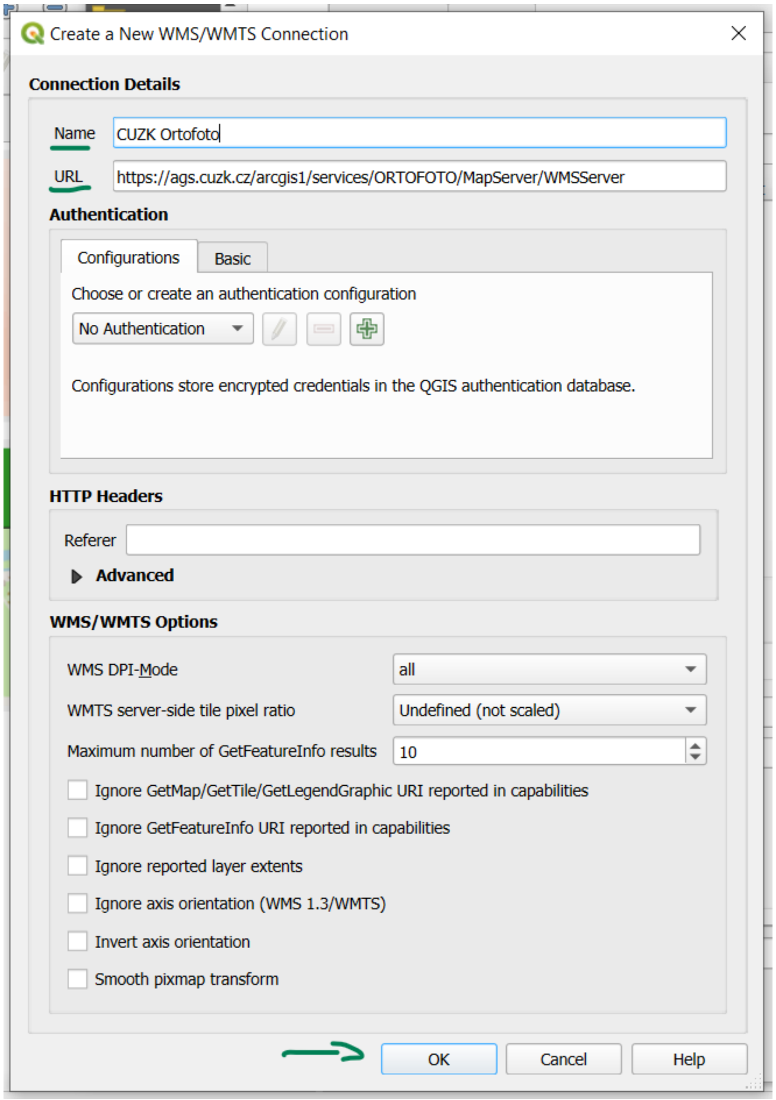
Coordinate Reference System: EPSG:4326 - WGS 84

☐ Use contextual WMS Legend

☐ Load as separate layers

Data Source Manager for WMS/WMTS connection.

In the dialog window for a new connection, you always must specify at least its name (what it will be called in the list of connections) and a URL of the WMS, WMTS, WFS, WCS server. Getting a correct URL of the server is crucial. It usually looks somewhat like https://ags.cuzk.cz/arcgis1/services/ORTOFOTO/MapServer/WMSServer – the last part containing the words wms, wmsserver, wfs, ows or alike. The other options in the dialog window control possible authentication methods, WMS server version and other advanced parameters.



Name: CUZK Ortofoto

URL: https://ags.cuzk.cz/arcgis1/services/ORTOFOTO/MapServer/WMSServer

Choose or create an authentication configuration

No Authentication

Configurations store encrypted credentials in the QGIS authentication database.

Referer:

WMS DPI-Mode: all

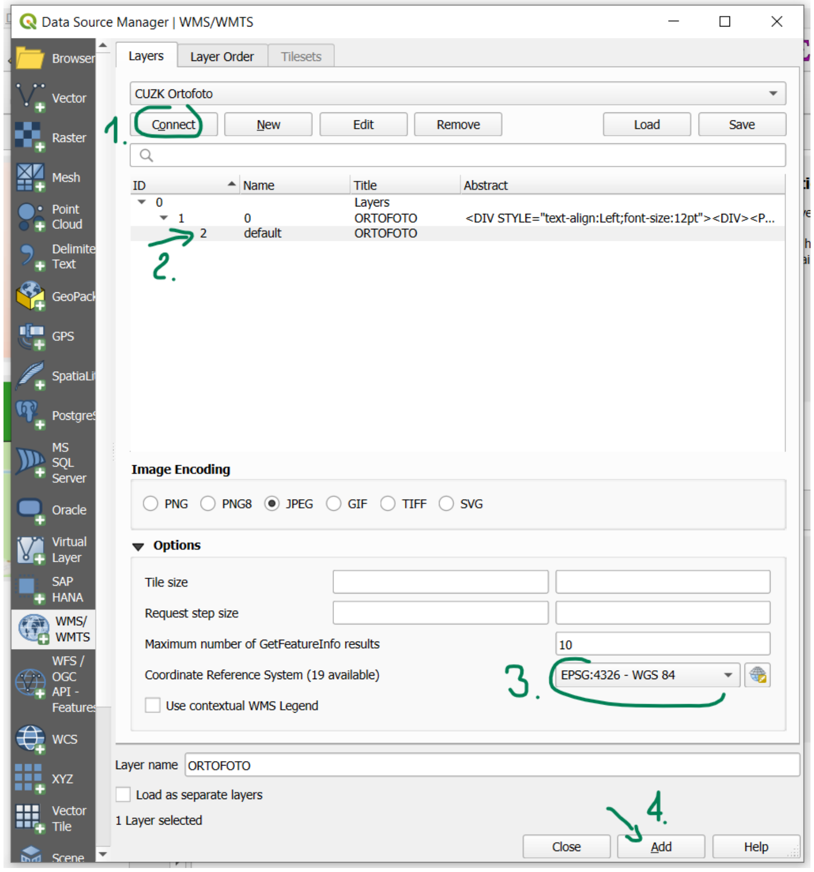
WMTS server-side tile pixel ratio: Undefined (not scaled)

Maximum number of GetFeatureInfo results: 10

☐ Ignore GetMap/GetTile/GetLegendGraphic URI reported in capabilities
☐ Ignore GetFeatureInfo URI reported in capabilities
☐ Ignore reported layer extents
☐ Ignore axis orientation (WMS 1.3/WMTS)
☐ Invert axis orientation
☐ Smooth pixmap transform

Correctly specified connection to a WMS server in QGIS.

Once the connection to the WMS / WMTS / WFS / WCS server is created, it remains available in the drop-down list and you do not need to specify it again every time you want to connect to the same server. You can even save the list of connections you have specified to a file and transfer it to another machine or another installation of QGIS. The “Save”/”Load” buttons serve this purpose.
Click “Connect” to connect to the selected WMS / WMTS / WFS / WCS server. A list of layers shall appear in the area in the middle of the window. From the layers in the list, select the one that is of your interest. You can usually change the file format in which the map or features will be loaded into the map canvas and the spatial reference system of the map / features. Once all is selected best for your needs, click “Add”.



CUZK Ortofoto

ID	Name	Title	Abstract
0		Layers	
1	0	ORTOFOTO	<DIV STYLE="text-align:Left;font-size:12pt"><DIV><P...
2	default	ORTOFOTO	

Image Encoding

○ PNG ○ PNG8 ● JPEG ○ GIF ○ TIFF ○ SVG

Options

Tile size

Request step size

Maximum number of GetFeatureInfo results: 10

Coordinate Reference System (19 available): EPSG:4326 - WGS 84

☐ Use contextual WMS Legend

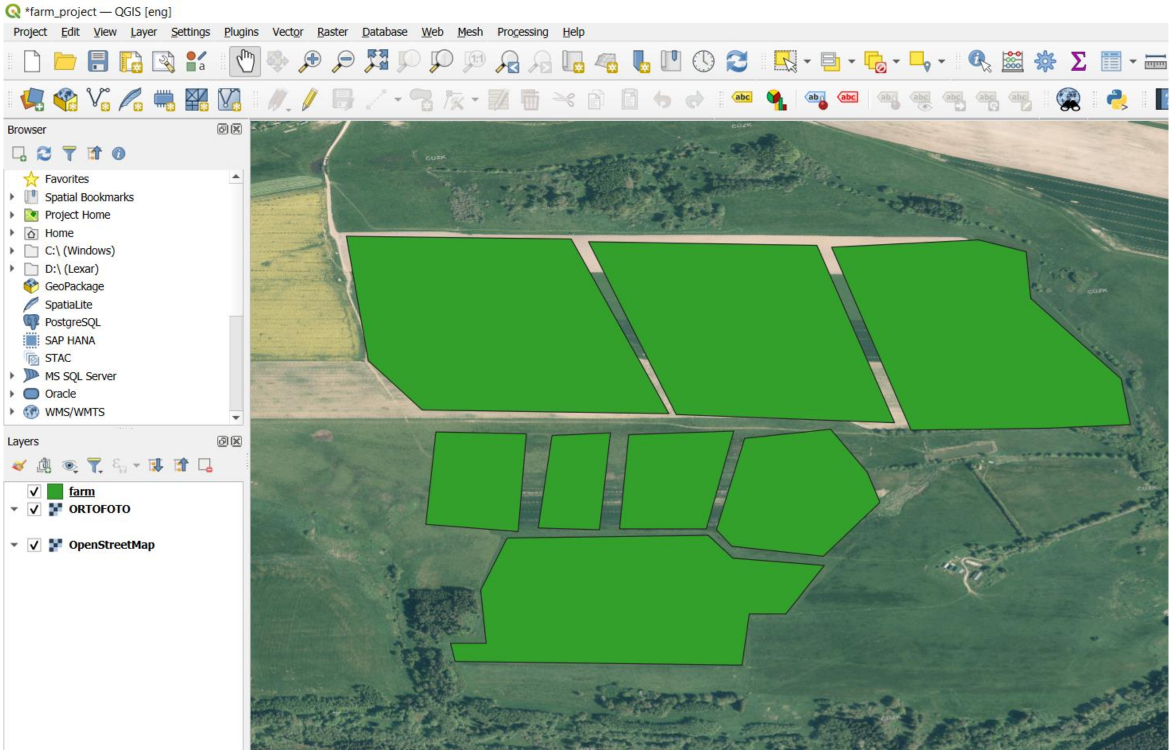
Layer name: ORTOFOTO

☐ Load as separate layers

1 Layer selected

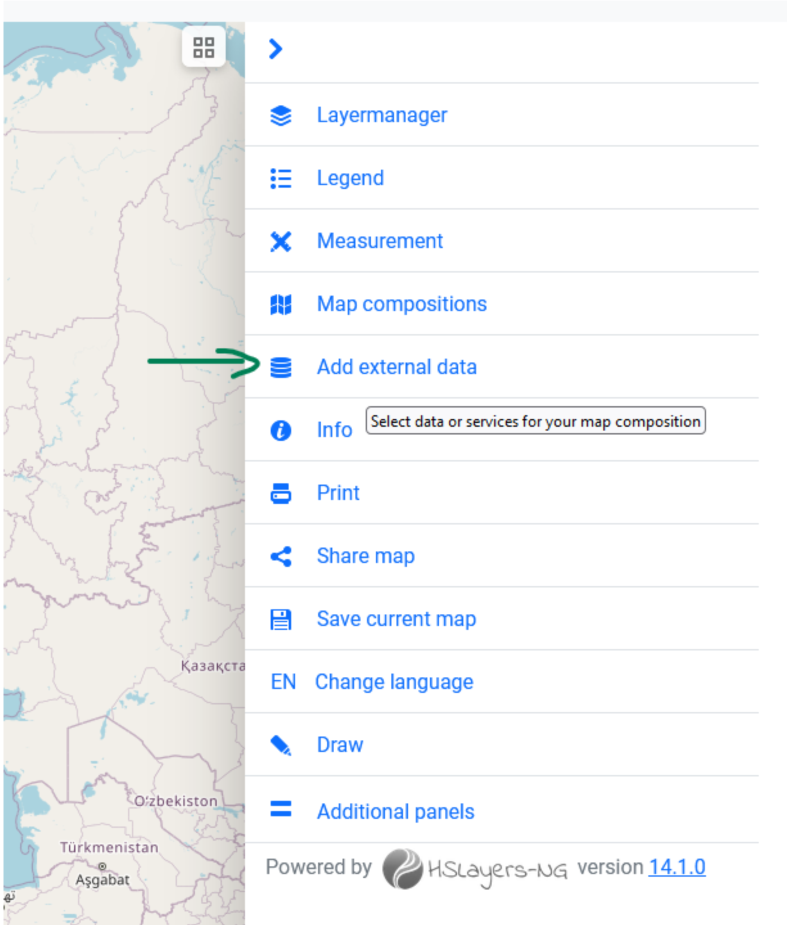
The connected WMS server provides only one layer called "ORTOFOTO". File format JPEG and spatial reference system WGS 84 were selected for the layer.

The selected layer is added on top in the "Layers" panel. You may want to reorder the layers with drag and drop to see the map content in the correct order.



Layer "ORTOFOTO", which is an aerial imagery, successfully loaded into QGIS.

In **HSLayers**-based **WebGIS** applications you can add data via the "Datasources" panel, which can be opened by the "Add external data" menu entry.

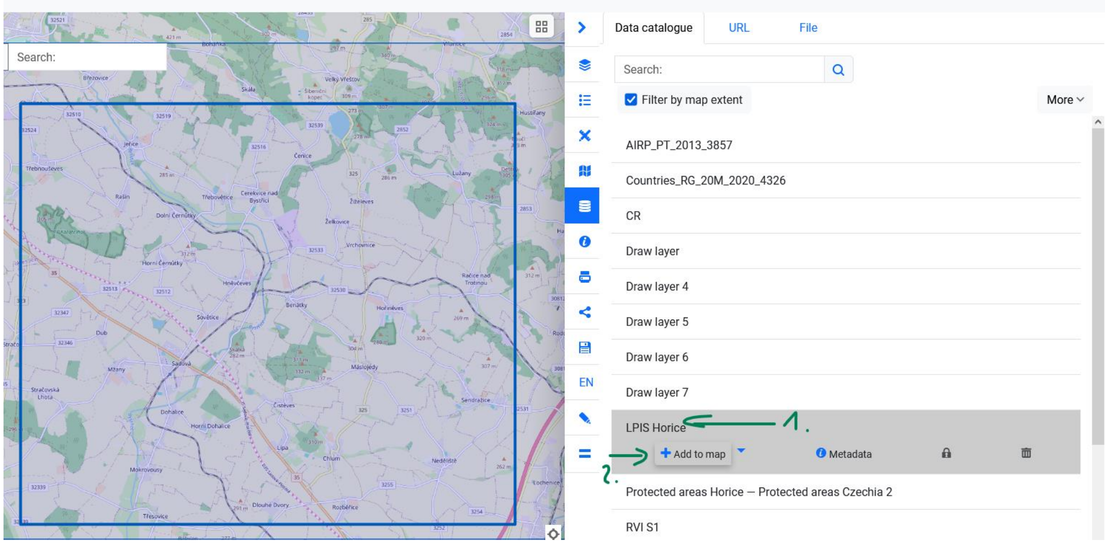


An HSLayers-based WebGIS application with expanded menu and "Add external data" highlighted.

It is possible to add data from three places:

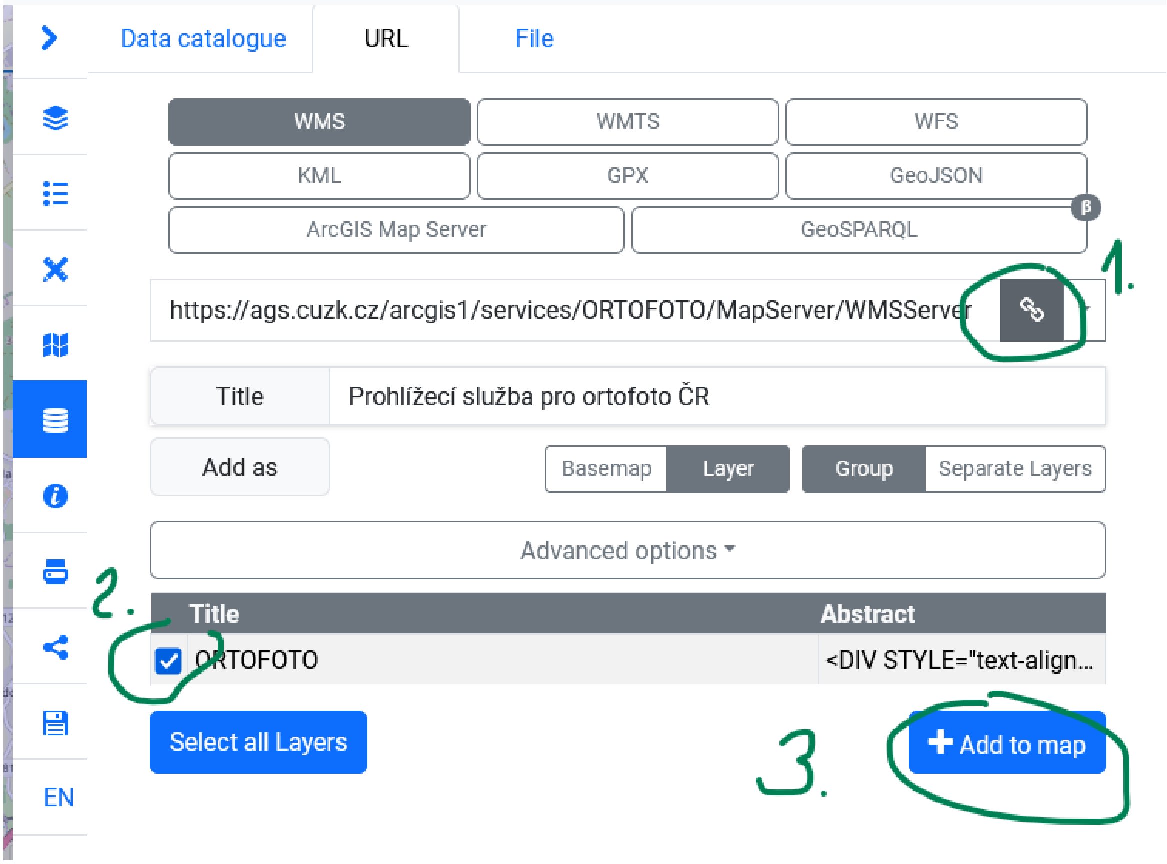
- The **data catalogue** connected with the WebGIS application.
- A file, database or a web service on the internet identifiable with an **URL**.
- A **file** in the user's local filesystem.

Adding data from the map catalogue is as simple as clicking the name of the interesting layer and then the "Add to map" button. As an asset, the geographical extent of the layer is highlighted in the map canvas.



Adding a layer “LPIS Horice” into the HSLayers-based WebGIS map.

Connecting to a WMS / WMTS / WFS layer from an HSLayers-based WebGIS application is somewhat similar to the approach in QGIS. You first have to input the URL of the remote server to which you want to connect. Then click the chainlink connection button, which loads the list of available layers and available options. After ticking the desired layer in the layer list, click “Add to map” and the layer will appear in the map canvas.



https://ags.cuzk.cz/arcgis1/services/ORTOFOTO/MapServer/WMSServer

Title: Prohlížecí služba pro ortofoto ČR

Add as: Basemap | Layer | Group | Separate Layers

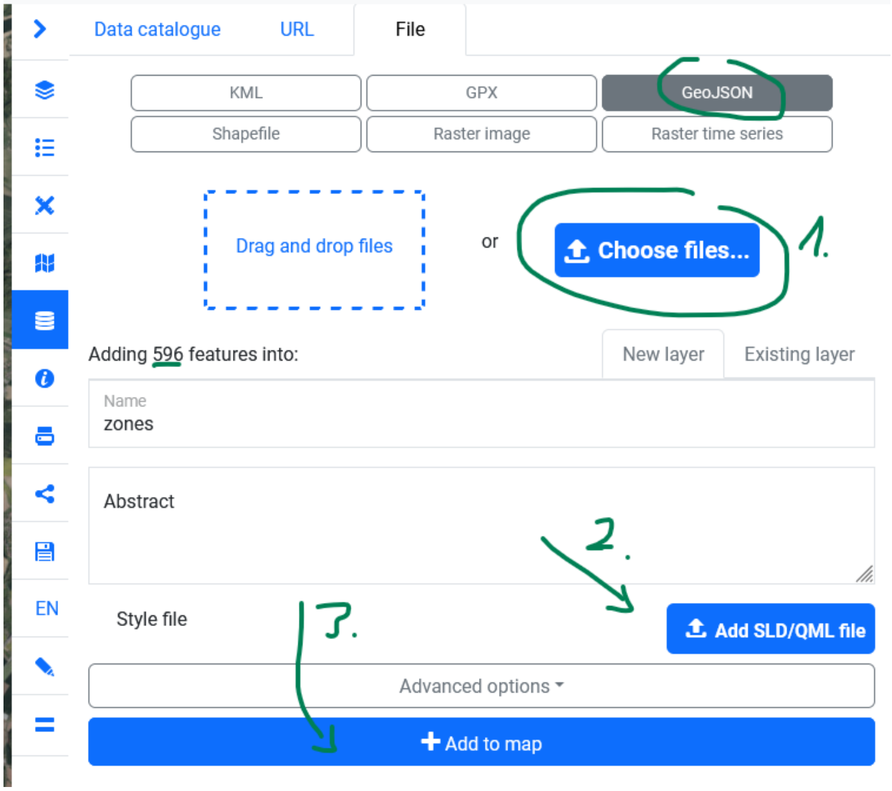
Title	Abstract
☑ ORTOFOTO	<DIV STYLE="text-align...

The provided WMS server only offers one layer “ORTOFOTO”, which is being added to the map.

You may want to reorder the map layers in the Layer Manager panel as the latest added layers are usually displayed on top.

An HSLayers-based WebGIS application with two layers. One from a WMS server and the other from a connected data catalogue.

The third option is to add a local file. This can be done by selecting the appropriate file in your device's file system. First you must select which format of data you wish to add (KML, GPX, GeoJSON, etc.), then you choose the file(s) from your device. Once the file(s) are read, the UI displays how many features will be added (in case of vector data). You have an option to rename the layer or to add a style file (in SLD or QML format) which will control the layer's appearance. If you won't provide a style file, the application will set a default style for all the data. Once done, click the "Add to map" button.



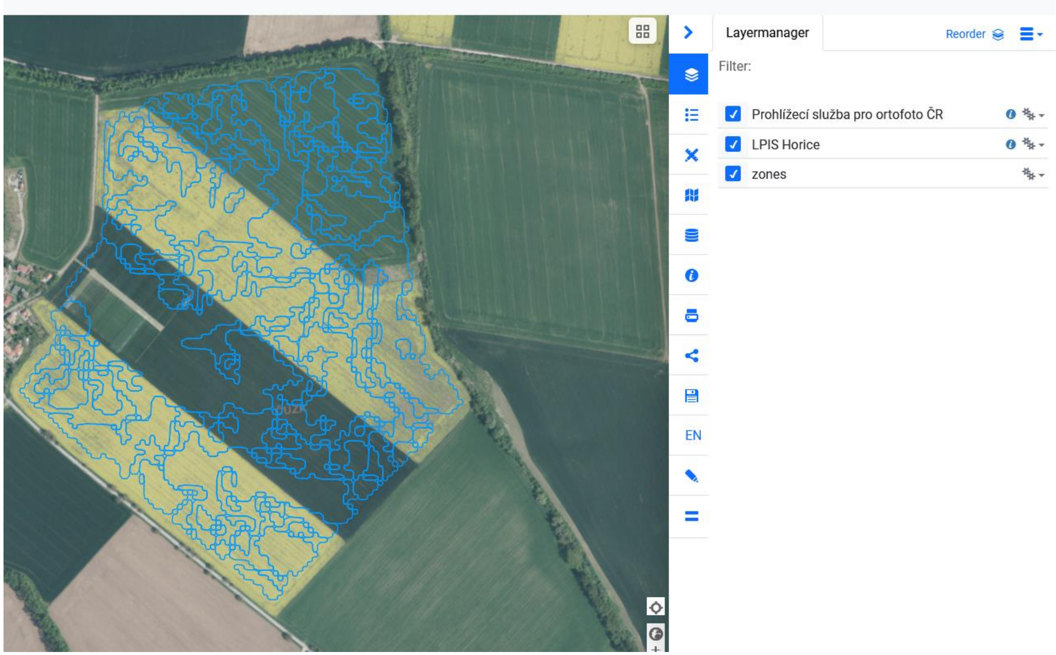
Adding 596 features into:

Name
zones

Abstract

Style file

Adding a GeoJSON file with 596 features into the HSLayers-based WebGIS application.



☑ Prohlížecí služba pro ortofoto ČR

☑ LPIS Horice

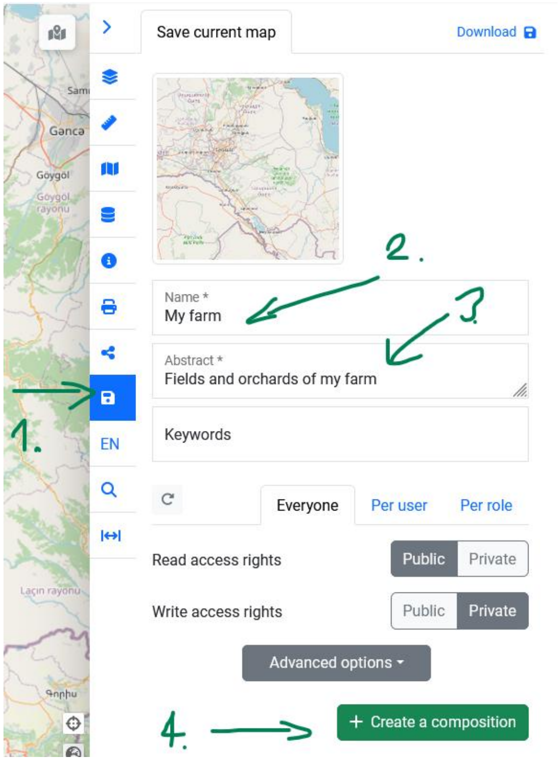
☑ zones

The local layer “zones” over the WMS layer “Prohlížecí služba pro ortofoto ČR”.

Drawing Maps with GIS

Refer to chapter *Introduction to GIS* in order to start a new project in QGIS.

In the following interactive window you can try yourself to create a new project in HSLayers-based WebGIS. A map project in this case is called a **map composition**. To create a new composition, navigate yourself to the “Save current map” panel from the side menu. Once you fill in a name and an abstract of the new composition, you can create the composition.



Name * My farm

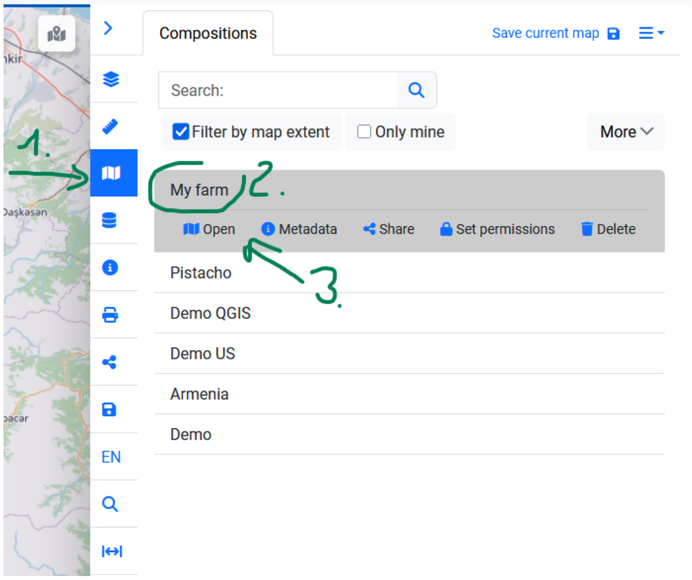
Abstract * Fields and orchards of my farm

Read access rights: Public

Write access rights: Private

The location of "Save current map" panel and its options in HSLayers-based WebGIS.

The map composition is stored in the compositions catalogue and can be loaded from the "Compositions" panel in the side menu. In this place you can also alter the map composition's access rights (via the "Set permissions" button), obtain a link for sharing the map composition with your co-workers, or delete the map composition if desired.



☑ Filter by map extent ☐ Only mine

My farm

Pistacho

Demo QGIS

Demo US

Armenia

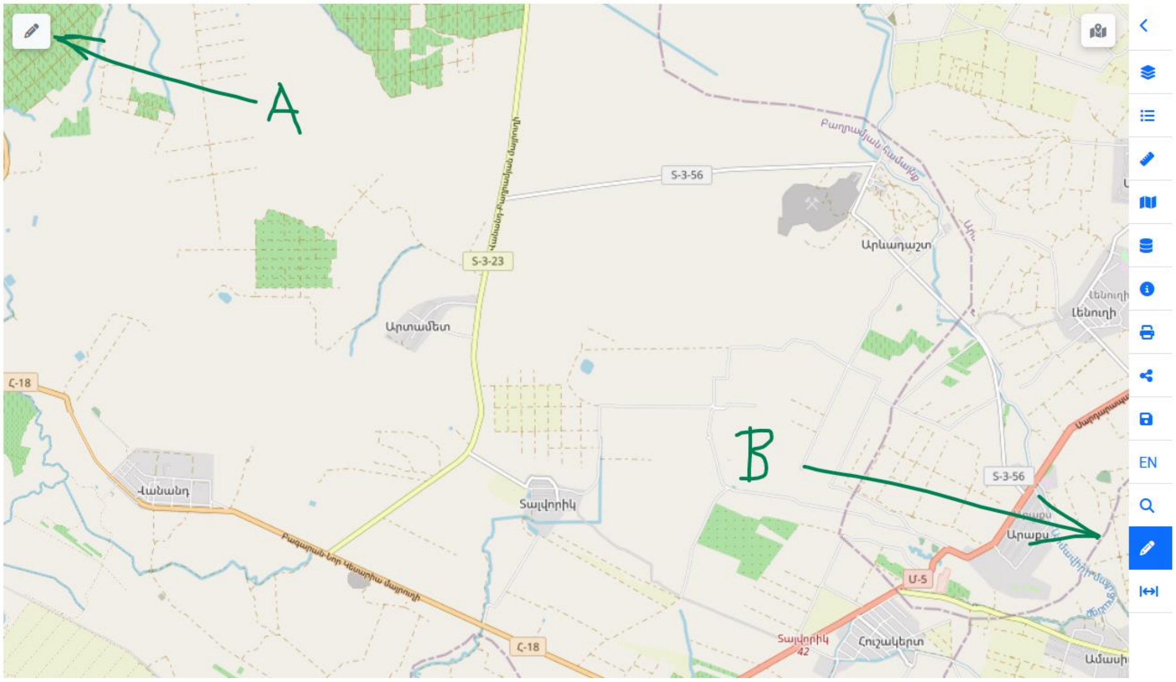
Demo

The location of "Compositions" panel and its options in HSLayers-based WebGIS.

After you make changes to the map composition, i.e. once some layers are added, removed or reordered, you have to go to the “Save current map” panel again, in order to save the changes you made.

Refer to chapters *Introduction to GIS*, *Geodata* and *Sources of Geodata* to learn how to create and add layers in QGIS or WebGIS. Refer to chapter *Geodata* to see how to vectorise features in QGIS.

Vectorising features in HSLayers-based WebGIS is possible when the “drawing” features are activated. These can be located in two different places in the user interface. Either in the “Draw” panel in the side menu or in the “Draw” toolbar in the upper left corner.



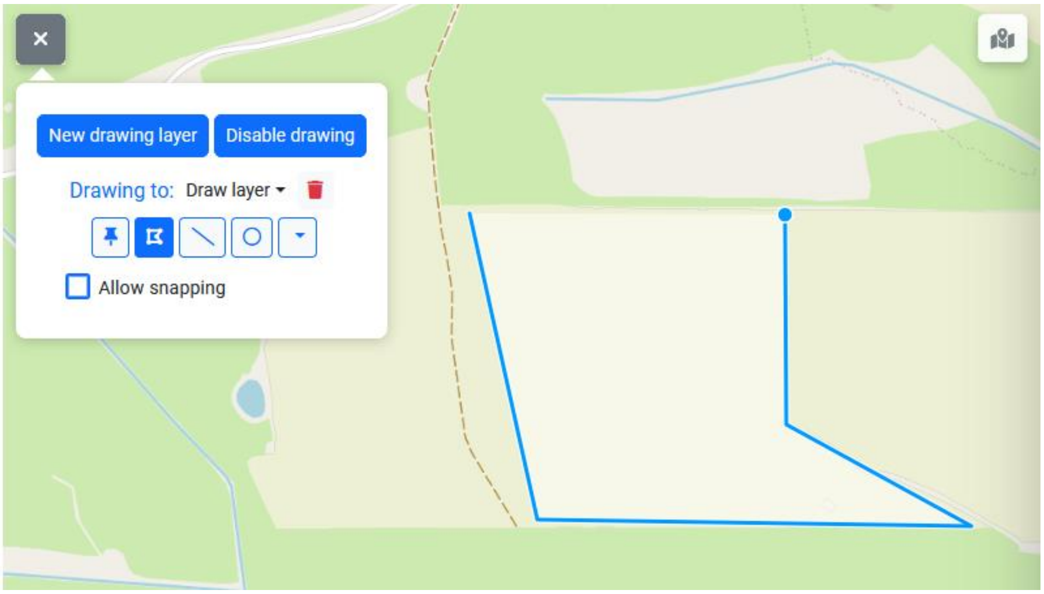
The location of the Draw toolbar (A) and Draw panel (B) in HSLayers-based WebGIS.

The process of drawing new features is the same in both panel and toolbar. Yet while toolbar drawing is only limited to creating new features and their basic editing, the drawing panel can perform more complex editing operations like intersection or union of features.

In order to start drawing features, first select a layer in which the features will belong. If no vector layer is available for drawing, you need to create a new layer first. Once a drawing layer is selected, you have an option to draw following types of features:

- points
- lines,
- polygons,
- circles (which are also polygons, but are drawn in a different fashion).

The vectorisation is performed by clicking into the map in the locations of desired vertices, just like when vectorising features in QGIS. When drawing circles, these can be drawn by just two clicks, which define the circle’s centre and its diameter. A drawing sketch is finished by double-click



Vectorising a field as a polygon using the "Draw" toolbar.

It is also possible to draw the features with a "free hand" when the SHIFT key is pressed on the keyboard. In that case, the line or polygon vertices are created uniformly while moving the mouse over the map.

A "free hand" sketch.

When the drawing is disabled with the "Disable drawing" button, it is possible to select the features which were already drawn, edit their vertices, edit, add or delete their attributes and also delete the selected features if needed.

Tabular Data in GIS

In GIS, tabular data are non-spatial data organised in tables, providing additional context and information to spatial data. To fully leverage GIS, it's important to connect **tabular data** (e.g. data in spreadsheets or databases) with spatial data, such as points, lines, and polygons on a map. This is usually done by linking an attribute table of geodata to an external table based on a common identifier, like a unique ID or name. For instance, a table listing cities with population data can be linked to a point layer representing city locations. Once linked, these attributes appear in the layer’s attribute table and can be displayed in the map, allowing users to visualise and analyse information like population density, area, or other characteristics directly with the spatial data.

Every spatial layer in GIS may have an attribute table that holds descriptive data about each feature in the layer. **Attribute tables** are organised in a familiar format like a spreadsheet, where each row represents a feature (e.g. a city or river), and each column represents an attribute (e.g. name, population, length).

Using queries, users can filter and analyse data within these tables. A query is essentially a search or filter applied to data based on specific conditions. For example, a query might isolate all cities with populations above 1 million. Queries make it easy to identify features that meet certain criteria, helping users answer questions.

Querying tabular data

An **attribute query** selects data based on specific values within an attribute table. It doesn’t rely on spatial relationships but rather on characteristics of the data itself, such as names, numbers, or categories. Attribute queries are similar to searching in a database or spreadsheet; you’re filtering rows that meet certain conditions.

Like in regular databases, **SQL (Structured Query Language)** is commonly used in GIS to perform attribute queries. SQL allows users to define specific conditions to find features that meet their criteria. For example, if you have a dataset of city locations with a "population" attribute, you could write an SQL query to find cities with populations over 1 million:

```
SELECT * FROM cities WHERE population > 1000000;
```

This query selects all rows from the "cities" table where the population is greater than 1 million, effectively highlighting these cities on the map. Further analysis can be limited to these selected cities with at least 1 million population.

Unlike attribute queries, **spatial queries** use the geographic relationships between features to find data. Spatial queries answer questions like which features are close to each other, intersect, or fall within a certain area. Instead of filtering based on data values, spatial queries focus on **where** features are in relation to one another.

Examples of spatial queries include:

- **Finding nearby features** (e.g. all schools within 2 kilometres of a hospital).
- **Identifying intersecting features** (e.g. rivers that cross a particular county).
- **Locating features within a boundary** (e.g. all parks within city limits).

For example, let’s say we want to find all parks within a 5-kilometre radius of a city centre point:

```
SELECT * FROM parks WHERE ST_Distance(city_center.geometry, parks.geometry) < 5000;
```

Here, the query uses ST_Distance (a spatial function) to calculate the distance between the city centre and each park, selecting only those parks within 5,000 metres (provided the spatial reference system uses metres as its base unit).

GIS software like **QGIS** allows users to combine both attribute and spatial queries for more complex analyses. For instance, if we want to find parks larger than 50 hectares within a 5-kilometre radius of a city centre, we could use a combination of attribute and spatial conditions:

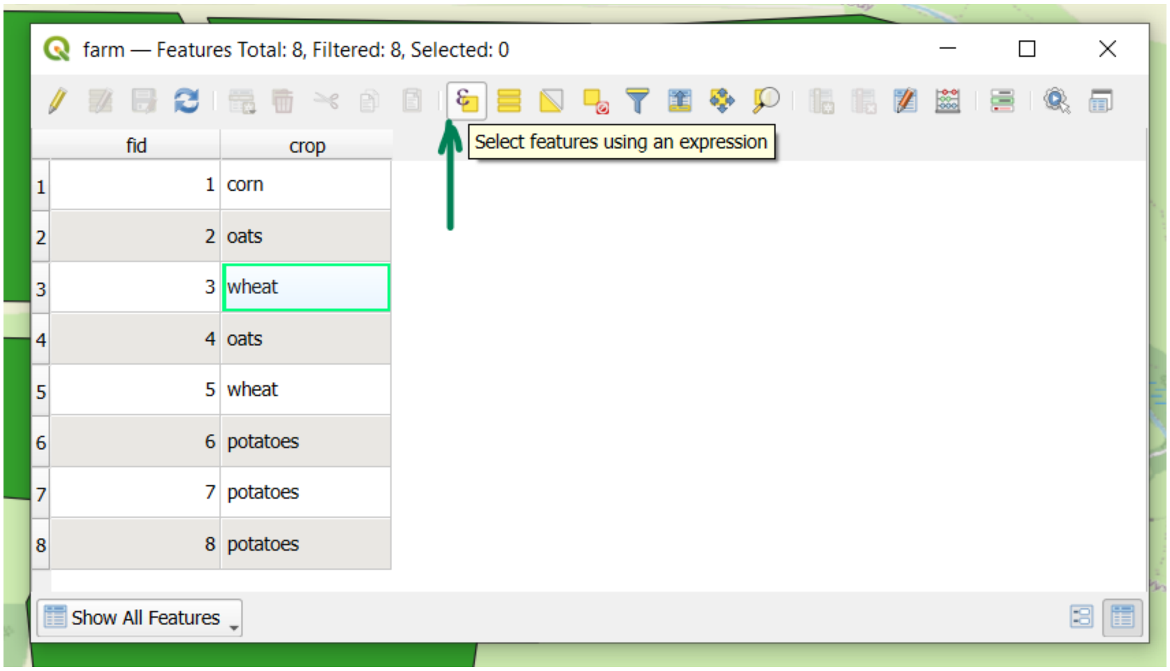
```
SELECT * FROM parks WHERE area > 50 AND ST_Distance(city_center.geometry,
parks.geometry) < 5000;
```

This query selects parks that are not only within 5 kilometres of the city centre but also have an area greater than 50 hectares (supposed that there is a column named “area” and its values are in hectares).

Querying data in QGIS

Tabular data in formats like CSV or Excel can be imported into QGIS. Using the "Join" function, these tables can be linked to spatial data by matching common fields, like a shared ID. Users can open the attribute table of any layer, add new columns, update values, or delete unwanted data. QGIS includes tools to query data by attribute. By using the “Select by Expression” or “Filter” options, users can apply custom filters based on expressions (e.g. finding all lakes larger than a certain area).

To make a query against a layer in QGIS, open the layer’s attribute table and locate the “Select by Expression” tool. This tool allows you to perform both attribute and spatial queries.

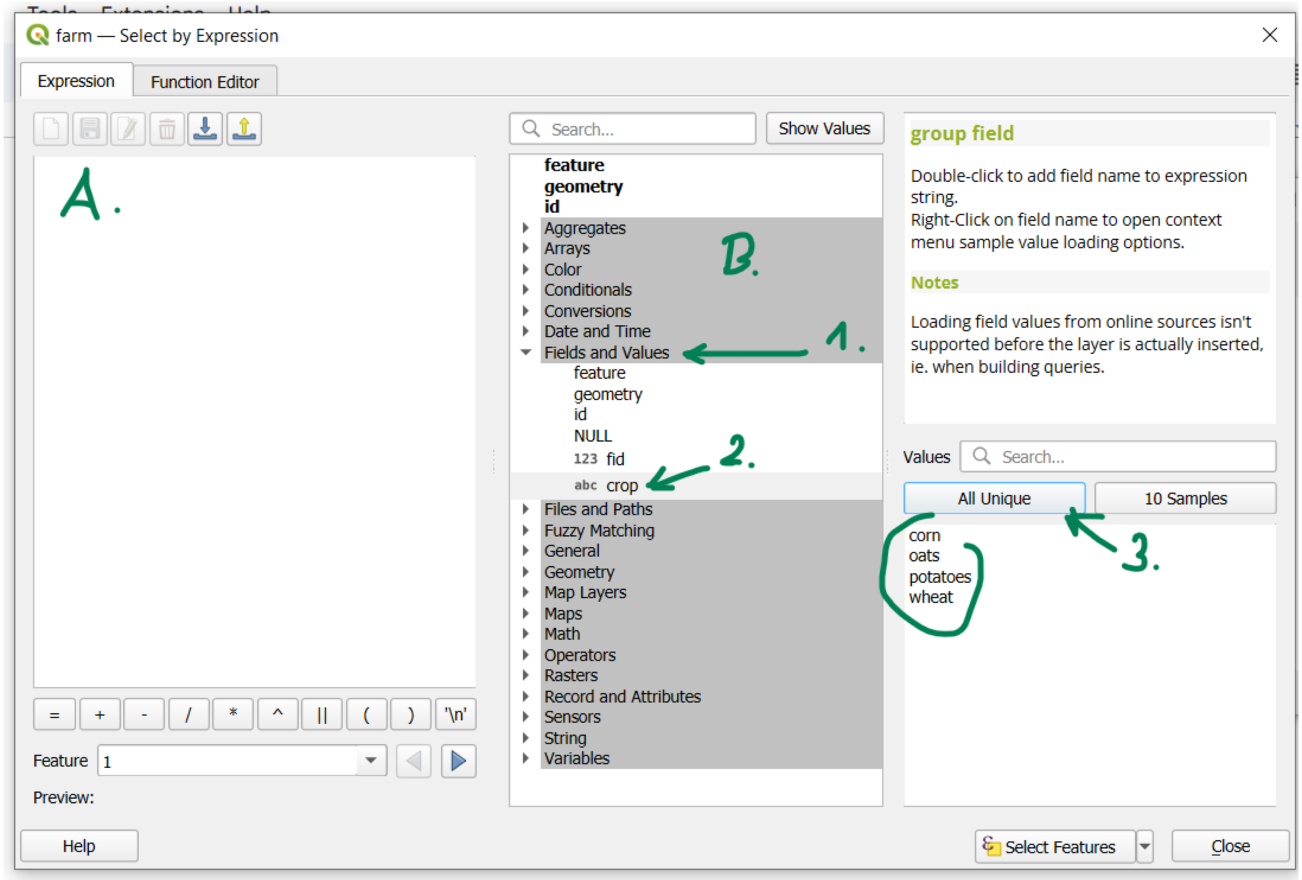


farm — Features Total: 8, Filtered: 8, Selected: 0

	fid	crop
1	1	corn
2	2	oats
3	3	wheat
4	4	oats
5	5	wheat
6	6	potatoes
7	7	potatoes
8	8	potatoes

Attribute table of the vector layer “farm” and the “Select features using an expression” button highlighted.

You can either write the SQL query directly into the textarea on the left (marked with a letter “A” on the image), or you can construct the query by clicking the options on the right (marked with a letter “B” on the image). Under the “Fields and Values” option you can find the attributes of this layer. By selecting an attribute and clicking the “All Unique” button you can get a list of all unique values which the selected attribute takes.



group field

Double-click to add field name to expression string.
Right-Click on field name to open context menu sample value loading options.

Notes

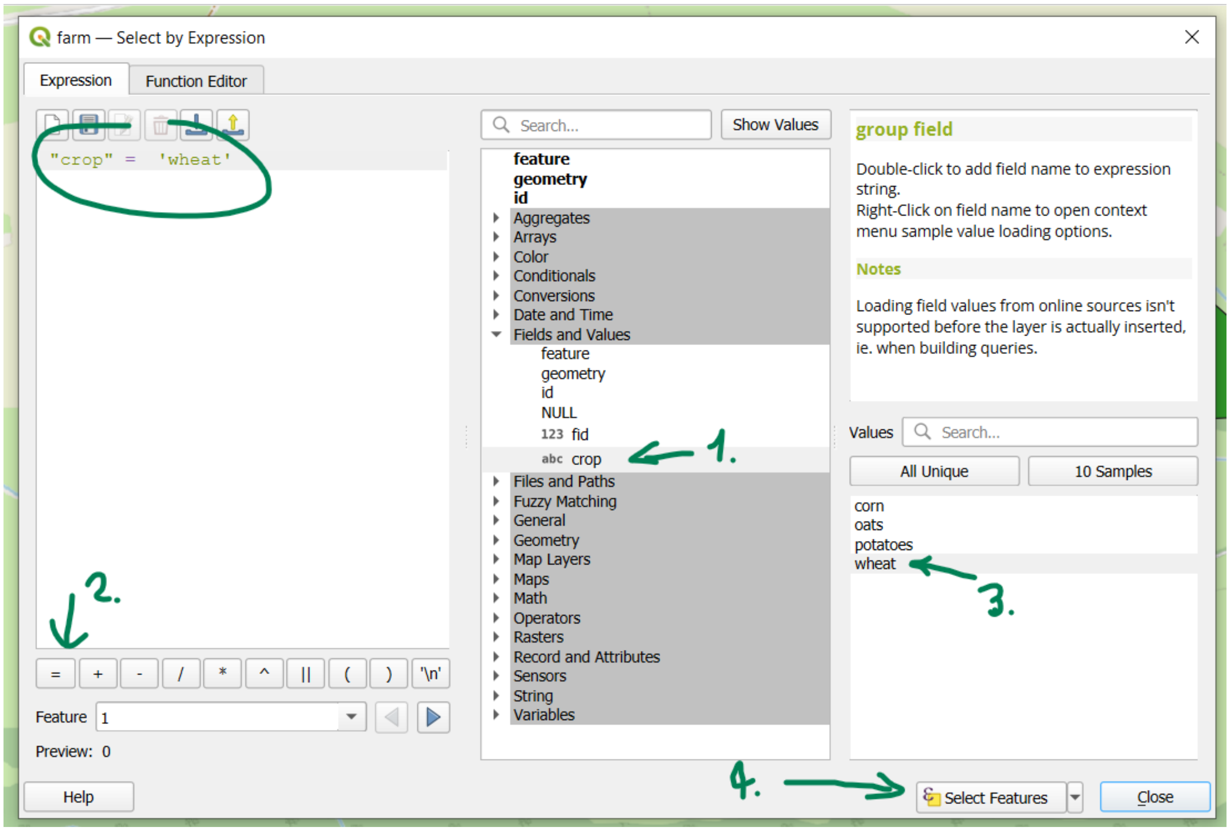
Loading field values from online sources isn't supported before the layer is actually inserted, ie. when building queries.

Select by Expression window showing four unique values (corn, oats, potatoes and wheat) of the attribute “crop” of the layer “farm”.

By double-clicking the attribute name, operators in the bottom left and the values in the list, you can construct a simple query like

"crop" = 'wheat'

That query shall select all features with attribute “crop” equal to value “wheat”. That shall represent real-world wheat fields on the farm. The query is executed once you click the button “Select Features”.



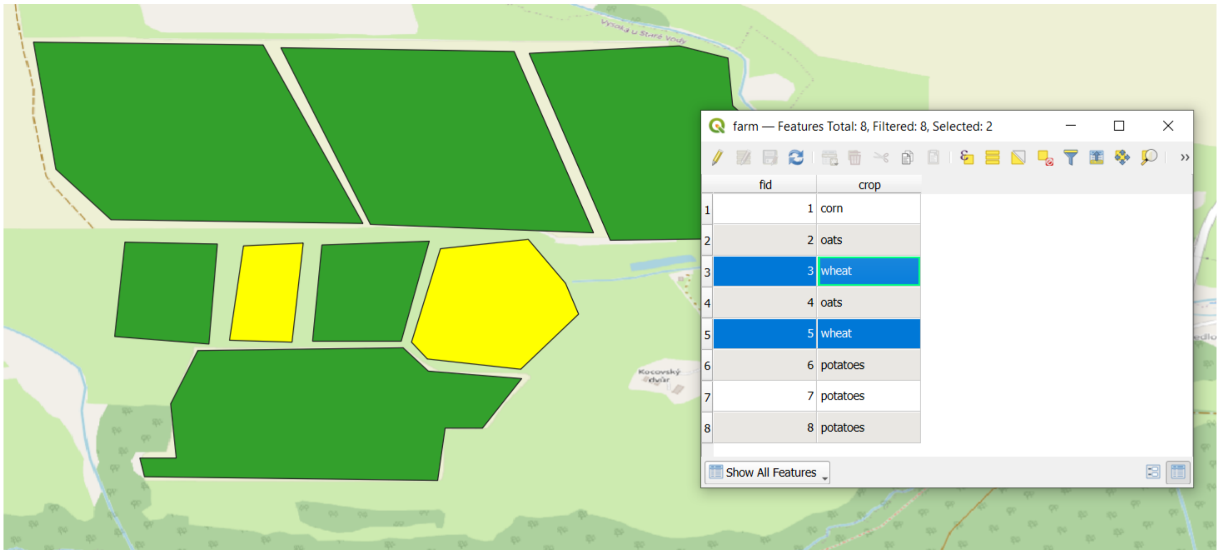
```
"crop" = 'wheat'
```

Double-click to add field name to expression string.
Right-Click on field name to open context menu sample value loading options.

Loading field values from online sources isn't supported before the layer is actually inserted, ie. when building queries.

"Select by Expression" window with a query to select all wheat fields.

The selected features are highlighted both in the attribute table and in the map canvas. When the features are selected you can make further analysis with only the selected features, export these selected features or combine them with other layers and features. To deselect the features, click the "Deselect all features from the layer" in the attribute table toolbar or in the main toolbar of the QGIS application.



farm — Features Total: 8, Filtered: 8, Selected: 2

	fid	crop
1	1	corn
2	2	oats
3	3	wheat
4	4	oats
5	5	wheat
6	6	potatoes
7	7	potatoes
8	8	potatoes

Wheat fields highlighted in the attribute table and in the map canvas.

Databases in GIS

Databases are an essential tool in modern GIS, especially for projects involving large datasets, complex queries, or multi-user environments. While file-based systems remain useful for smaller-scale tasks, the ability of spatial databases to handle advanced spatial operations, ensure data integrity, and integrate with other systems makes them indispensable for enterprise-level GIS applications. Understanding the strengths and trade-offs of databases empowers GIS professionals to choose the right tool for their needs.

Databases are structured systems for storing, managing, and retrieving data efficiently. In the context of GIS, databases play a critical role in handling spatial data, offering powerful tools for querying, analysing, and visualising geographic information. They provide a robust alternative to file-based storage systems, particularly as the volume and complexity of spatial data grow.
While files like Shapefiles or GeoJSONs are common for storing spatial data, databases offer several advantages. Files are straightforward and portable, making them ideal for small projects or data sharing. However, they can become cumbersome as datasets increase in size, complexity or number. Databases, on the other hand, centralise data storage, enabling efficient management, secure multi-user access, and support for complex queries and analysis. Spatial databases, such as PostGIS or SpatiaLite, extend traditional database functionality to handle geographic data like points, lines, polygons and raster data. Spatial databases extend the capabilities of traditional databases to store and analyse spatial data. While non-spatial databases manage alphanumeric data with columns and rows, spatial databases introduce specialised data types (e.g. geometry and topology rules) and indexing systems (e.g. R-trees) for efficient spatial querying. They enable operations such as finding intersections, calculating distances or running spatial joins directly in the database. Tools like PostGIS, Oracle Spatial and Microsoft SQL Server Spatial are examples of spatially enabled databases.

Pros and Cons of Using Databases for Spatial Data

Pros:

1. **Centralised Storage**: Databases can store and manage vast amounts of data in one place, eliminating redundancy.
2. **Scalability**: They handle large datasets efficiently and support concurrent access by multiple users.
3. **Advanced Querying**: Databases enable complex spatial and attribute queries using languages like SQL, which is much more powerful than file-based tools.
4. **Data Integrity and Security**: Databases ensure data consistency and provide access control mechanisms to secure sensitive information.
5. **Integration**: Databases can integrate spatial and non-spatial data, facilitating advanced analyses.

Cons:

1. **Setup Complexity**: Databases require setup, configuration and maintenance, which might be overkill for small-scale projects.
2. **Resource-Intensive**: Databases require more computational resources and expertise compared to simple file management.

3. **Less Portable**: Sharing database content often involves exporting or providing remote access, which can be less straightforward than sharing a file.

Database Management Systems for geodata

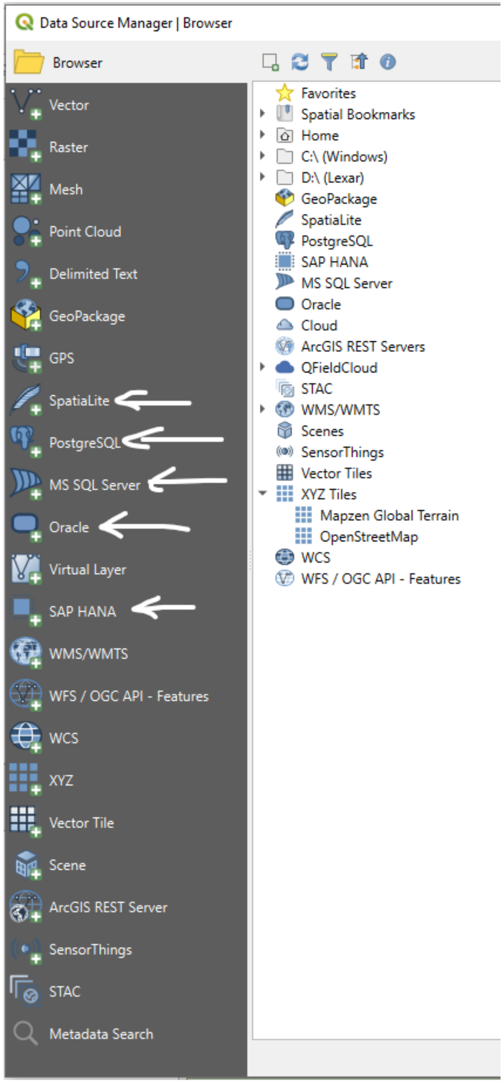
Some common Database Management Systems (DBMS) frequently used for geospatial data:

- **SQLite with SpatiaLite**. SpatiaLite is an extension to SQLite that enables the storage and management of spatial data within a lightweight, file-based database. The file extension is .sqlite or .db, and it supports both vector and raster data, along with spatial indexing and geospatial queries. SpatiaLite is often used for standalone GIS applications and is valued for its portability and ability to handle spatial data without the need for a separate server.
- **PostgreSQL with PostGIS**. PostgreSQL is an open-source relational database management system that, with the PostGIS extension, supports the storage and querying of spatial data. It is used to store large-scale vector and raster datasets with advanced spatial indexing and geospatial operations. The format does not have a specific file extension, as it is a server-based system, and data is managed through SQL queries, making it ideal for enterprise-level GIS applications and multi-user environments.
- **MySQL with Spatial Extensions**. MySQL, one of the most widely used open-source relational database management systems, includes support for spatial data through its spatial extensions. These extensions allow MySQL to store, query, and manipulate geometric and geographic data types, but it lacks support for 3D geometries and advanced spatial functions like raster processing or topological relationships.
- **Microsoft SQL Server with Spatial Features**. MS SQL Server is a relational database management system that, with the Spatial Data extension, supports the storage and querying of spatial data. It can store both vector and raster data, offering advanced spatial indexing, geospatial functions, and the ability to perform spatial queries. The format does not have a specific file extension, as it is a server-based system, and spatial data is managed within the database using SQL Server’s spatial data types and queries.
- **Oracle Spatial and Graph**. Oracle Spatial is an extension of the Oracle Database that enables the storage, management, and analysis of spatial data. It supports both vector and raster data, offering powerful spatial indexing, geospatial functions, and advanced querying capabilities. As a server-based system, it does not have a specific file extension, with spatial data managed through Oracle's spatial data types and SQL queries, making it ideal for enterprise-level GIS applications.
- **SAP HANA with Spatial Features**. SAP HANA is an in-memory, column-oriented relational database management system that supports spatial data through its SAP HANA Spatial extension. It allows for the storage and analysis of both vector and raster data, offering advanced spatial indexing and geospatial queries. As a server-based system, it does not have a specific file extension, with spatial data stored and managed within the database using SAP HANA’s spatial data types and SQL queries, making it suitable for enterprise-level GIS and real-time analytics applications.
- **Google BigQuery GIS**. BigQuery GIS is a cloud-based platform for storing, querying, and analyzing geospatial data within Google's **BigQuery**, a fully managed data warehouse designed for large-scale analytics. With its GIS capabilities, BigQuery enables users to integrate and analyze spatial data alongside traditional datasets using SQL. Spatial and non-spatial data can be combined seamlessly for multidimensional analysis. For instance, businesses can analyze sales data by region or compare demographic information with geospatial boundaries. Built on

BigQuery's scalable architecture, it can handle massive geospatial datasets with fast processing speeds, making it ideal for enterprise-level and real-time analytics.

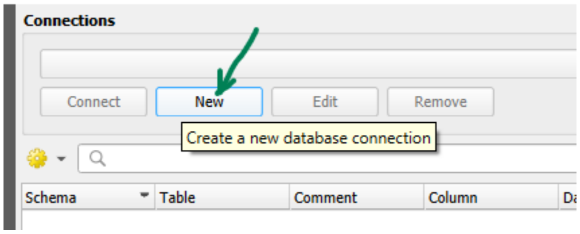
Connecting to a spatial database from QGIS

QGIS offers a wide variety of options to connect to a spatial database. As of version QGIS 3.40, these options include: GeoPackage, SpatialLite, PostgreSQL, MS SQL Server, Oracle and SAP HANA database management systems.



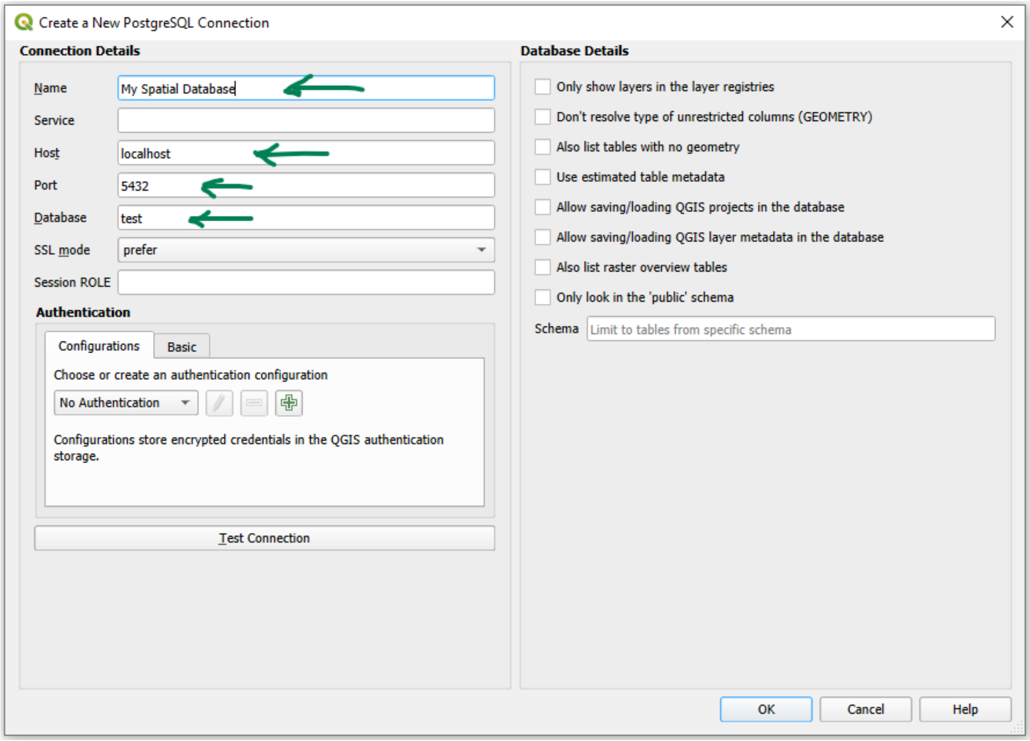
Various database connection options in QGIS's Open Source Data Manager.

In order to connect to a spatial database, a new connection must be defined first.



Creating a new database connection in QGIS's Open Source Data Manager.

At least the following information must be provided when connecting to a PosgreSQL database: host, port, database name and connection name. Oracle, SAP HANA and MS SQL Server require similar options.


Create a New PostgreSQL Connection

Connection Details

Name: My Spatial Database
Service:
Host: localhost
Port: 5432
Database: test
SSL mode: prefer
Session ROLE:

Authentication

Configurations | Basic

Choose or create an authentication configuration

No Authentication

Configurations store encrypted credentials in the QGIS authentication storage.

Test Connection

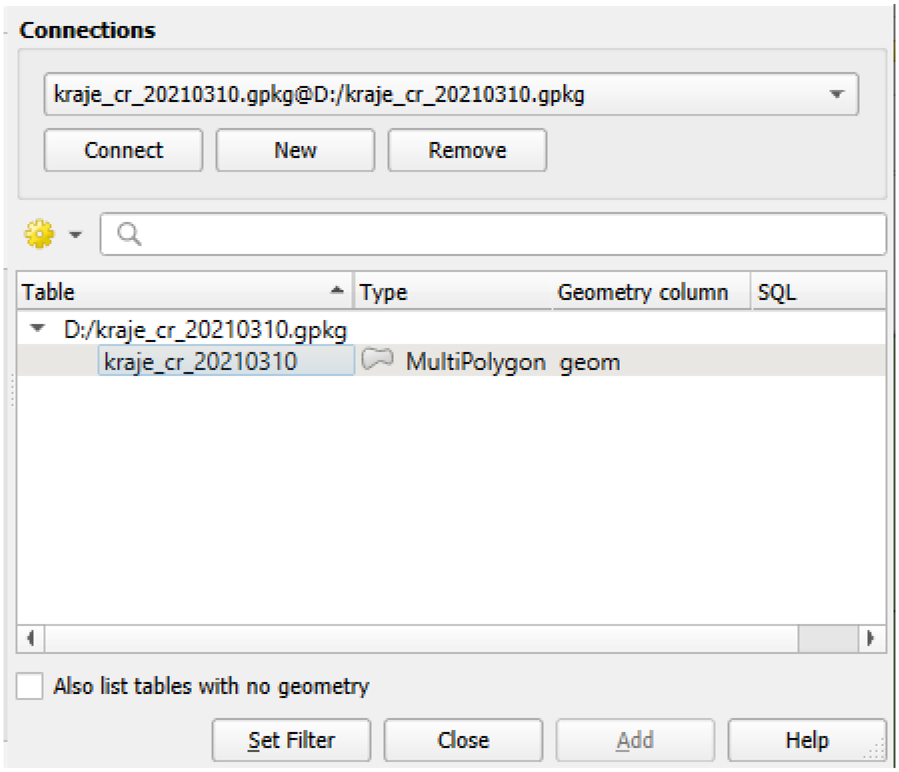
Database Details

☐ Only show layers in the layer registries
☐ Don't resolve type of unrestricted columns (GEOMETRY)
☐ Also list tables with no geometry
☐ Use estimated table metadata
☐ Allow saving/loading QGIS projects in the database
☐ Allow saving/loading QGIS layer metadata in the database
☐ Also list raster overview tables
☐ Only look in the 'public' schema

Schema: Limit to tables from specific schema

Defining a new connection to a PosgreSQL database "test" running on localhost:5432.

On the other hand, GeoPackage and SpatiaLite are so-called **file databases**, which are defined by their file and location. After selecting a table from the database, the geodata can be added to the project by clicking the "Add" button.



kraje_cr_20210310.gpkg@D:/kraje_cr_20210310.gpkg

Table	Type	Geometry column	SQL
D:/kraje_cr_20210310.gpkg			
kraje_cr_20210310	MultiPolygon	geom	

☐ Also list tables with no geometry

Connected GeoPackage with one table “kraje_cr_20210310” containing multi-polygons in a column named “geom”.

Connecting to a spatial database from WebGIS

HSLayers-based WebGIS is well integrated with the layer management system **Layman**. Layman is a geodata publishing system, responsible for data saving, loading, updating and access regulation. Layman stores the data in a PostGIS database. Two major types of data can be stored in Layman:

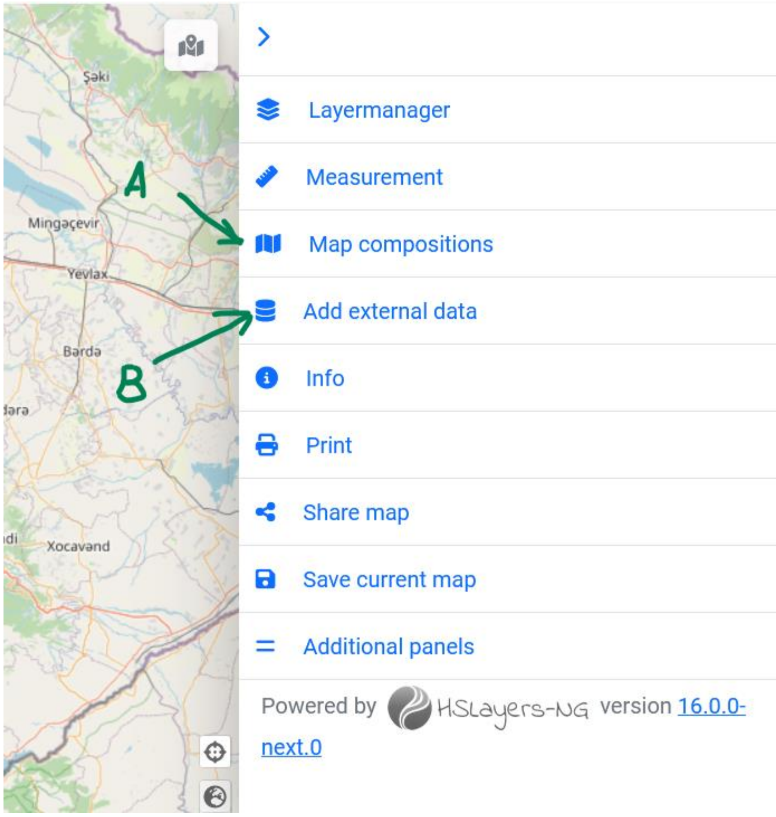
- individual map layers and
- map compositions.

Alongside that, Layman also stores information about the layer’s styles and about users and their access privilege.

In order to connect to the Layman database, a connection link must be set-up in the HsConfig object in HSLayers-NG. E.g.:

```
datasources: [
        {
          title: 'Layman Catalogue',
          url: 'https://vetfarm.org/layman-proxy',
          type: 'layman',
        },
      ]
```

If the correct link is provided and if the Layman system is running properly at the given location, it is then possible to find layers from Layman in the “Data catalogue” panel in the side-menu and map compositions from Layman in the “Compositions catalogue” panel in the side-menu.



Compositions catalogue (A) and Datasource catalogue (B) menu items in the HSLayers-based WebGIS as a mean to work with data from spatial database.

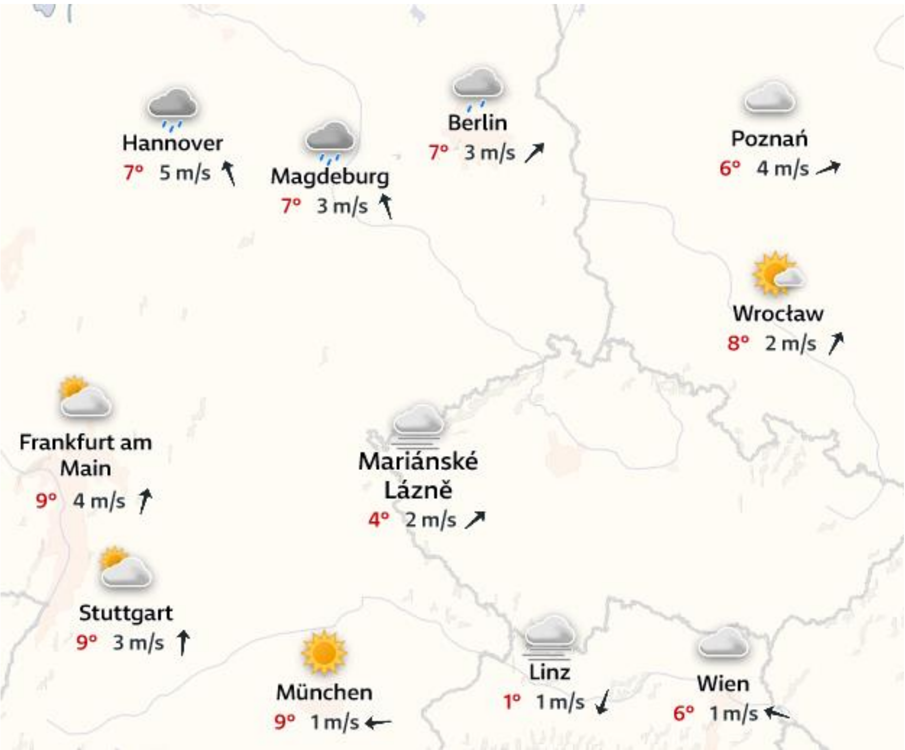
Cartographic Visualization Techniques I

Cartographic visualization techniques refer to the methods and approaches used to represent geographic data visually on a map. These techniques focus on effectively conveying spatial relationships, patterns and trends through the use of symbols, color schemes and thematic representations.

Cartographic design is centered around creating maps as simplified and scaled-down representations of reality. Since maps reduce the complexity of the real world, their content must also be carefully simplified to ensure clarity and usability. This process involves **generalization**, which reduces detail by omitting less important features, aggregating similar elements, or simplifying shapes, making the map more readable and focused on its purpose. A critical aspect of cartographic design is the use of **symbols**, which are graphical representations—such as points, lines, and areas—that stand in for real-world features like cities, roads or forests. Effective cartographic design balances simplicity with accuracy, ensuring the map communicates essential information without overwhelming or misleading the user.

Example of some common symbols used in maps. Yet their meaning can vary in different kinds of maps. Source: maki symbol set.

Thematic maps use **symbology**—a set of symbols —to communicate their message effectively. For example, a map showing global climates might use color gradients (green for tropical, orange for arid, white for polar zones), while a population density map might use dot density or varying shades of a single color to represent data intensity. A familiar real-world example is the **weather map**, which uses symbols like sun icons for clear skies or raindrop symbols for precipitation to communicate current conditions clearly.



An excerpt from a weather forecast map with various symbols, like cloud or sun, representing expected weather conditions. Source: yr.no

The phenomena represented on thematic maps can be **qualitative** (describing types or categories, like soil types or land cover) or **quantitative** (showing measurements or amounts, like rainfall totals or income levels). Symbology is critical for clarity and must align with the type of data. For instance, **ordinal data**—a subtype of qualitative data with an inherent order, such as "high," "medium," and "low" risk zones—may use progressively darker shades of a color to signify increasing severity. Quantitative data, such as annual rainfall, often uses proportional symbols (e.g. circles sized according to rainfall) or graduated color scales to represent varying data magnitudes.

Visual Variables

A change of a phenomenon value is represented in a map by the change of the symbols properties. For example, in a map showing earthquake magnitudes, earthquake epicentres can be represented using circles, where the size of the circle changes based on the magnitude of the earthquake. A small earthquake might be shown with a small circle, while a large earthquake is represented with a much larger circle. Another example is a population density map, where areas with higher population density might be represented with darker shades of a single colour, while areas with lower density are depicted with lighter shades. These two examples demonstrate the change of symbol size and the change of symbol colour respectively to visualise the change of phenomena value.

The changing symbol's properties are called **visual variables** and were described by a French cartographer *Jacques Bertin*. The core visual variables are:

- **Size** – can represent phenomena by scaling symbols proportionally to their data values, such as larger circles indicating higher population.
- **Shape** – can represent phenomena in thematic maps by varying the form of symbols to distinguish categories, such as triangles for mountains, circles for cities and squares for industrial zones.
- **Colour hue** – can represent phenomena in thematic maps by using different hues to distinguish categories, such as yellow for wheat fields, green for orchards and violet for lavender fields.
- **Colour lightness** – can represent phenomena in thematic maps by varying the brightness of a colour to indicate data intensity, such as lighter shades representing lower population density and darker shades representing higher density.
- **Colour saturation** – can represent phenomena in thematic maps by using more saturated colours to indicate higher values of a variable, such as dark green for areas with high rainfall and lighter green for areas with lower rainfall.
- **Orientation** – can represent phenomena in thematic maps by varying the angle or direction of symbols to indicate different categories or trends, such as vertical lines for urban areas and horizontal lines for agricultural zones.
- **Pattern/Texture** – can represent phenomena in thematic maps by using different patterns to distinguish categories or data ranges, such as solid fill for agricultural areas and crosshatch patterns for industrial zones.
- **Height** – can represent phenomena in thematic maps by varying the elevation of symbols to indicate data values, such as taller bars representing areas with higher GDP and shorter bars representing areas with lower GDP.

Colour hue, colour saturation, and colour brightness are all aspects of colour that influence how we perceive it. In brief: **colour hue** defines the actual colour (red, blue, etc.), **saturation** describes the intensity or vividness of the colour and **brightness** refers to how light or dark the colour appears.

In digital, animated, haptic (for visually impaired users) or other maps, additional non-visual variables can be used for the same purpose. These variables include, but are not limited to:

- **Duration** – can represent phenomena by adjusting how long a symbol or feature appears or remains highlighted, such as using flashing points to indicate the length of time an event (e.g. a road closure or natural disaster) affects a location.
- **Pressure** – can represent phenomena by varying the force required to interact with the map interface, such as increasing resistance to indicate elevation or density at specific locations.
- **Vibration** – can be used in a haptic map to convey information by triggering specific vibration patterns when a user touches certain areas of the map, such as indicating land types, hazard zones, or proximity to a point of interest.
- **Friction** – can represent phenomena in a haptic map by changing the resistance felt when interacting with specific areas, such as increasing friction to indicate rough terrain or restricted zones.
- **Loudness** – can represent phenomena by adjusting the volume of auditory feedback to indicate intensity, such as louder sounds for higher population density or stronger weather conditions.

Choropleth and Chorochromatic Maps

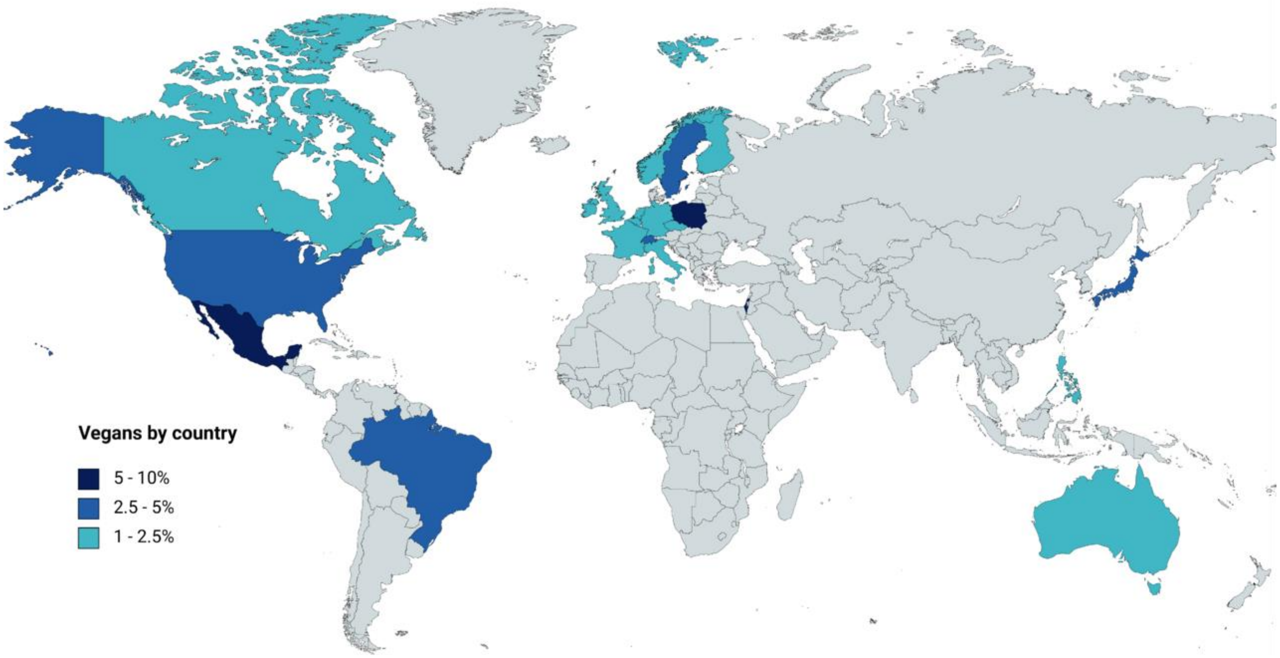
Choropleth maps and chorochromatic maps are often considered one category of thematic maps, but they differ in one key aspect. While both types of maps use colour to convey information, **choropleth maps** specifically deal with **numerical data**, whereas **chorochromatic maps** deal with **categorical data**. This overlap in the use of colour for mapping can lead to misunderstanding the types of data being represented.

Chorochromatic maps use different colours (colour hues) to represent **qualitative variables**, such as land use types, political boundaries or cultural regions, where each colour corresponds to a distinct category. Areas depicted in chorochromatic maps can be determined by socio-economic factors (commonly administrative units) or by physical-geographic phenomena (geological maps, geomorphological maps, botanical regions, altitudinal zonation, …). In the course "Mapping Fundamentals", a geological map of Britain by *William Smith* was mentioned, which is an example of a chorochromatic map with physical-geographic boundaries. A common example of a chorochromatic map with administrative boundaries are political maps. In chorochromatic maps, the cartographer has to deal with the limitation that any two adjacent areas must have distinct colours to clearly differentiate the qualitative categories they represent. There are online tools like ColorBrewer by Cynthia Brewer which helps create colour palettes for chorochromatic and choropleth maps.

©2024 Milos Popovic I Data: ©ESA WorldCover project 2021

Chorochromatic map showing land cover of Italy divided into 10 distinct categories. The 3D visual effect is adding additional information about elevation on one hand, but it can cause colour misinterpretation on the other hand. Source: Milos Popovic, 2024, via LinkedIn.

Choropleth maps use varying shades (colour saturation) or colours (colour brightness) to represent the distribution of a **quantitative variable** across geographic areas, with darker or more intense colours typically indicating higher values and lighter colours representing lower values, such as population density or income levels. In the course “Mapping Fundamentals”, statistical maps by *Pierre Charles Francois Dupin* were mentioned, which are great examples of choropleth maps.



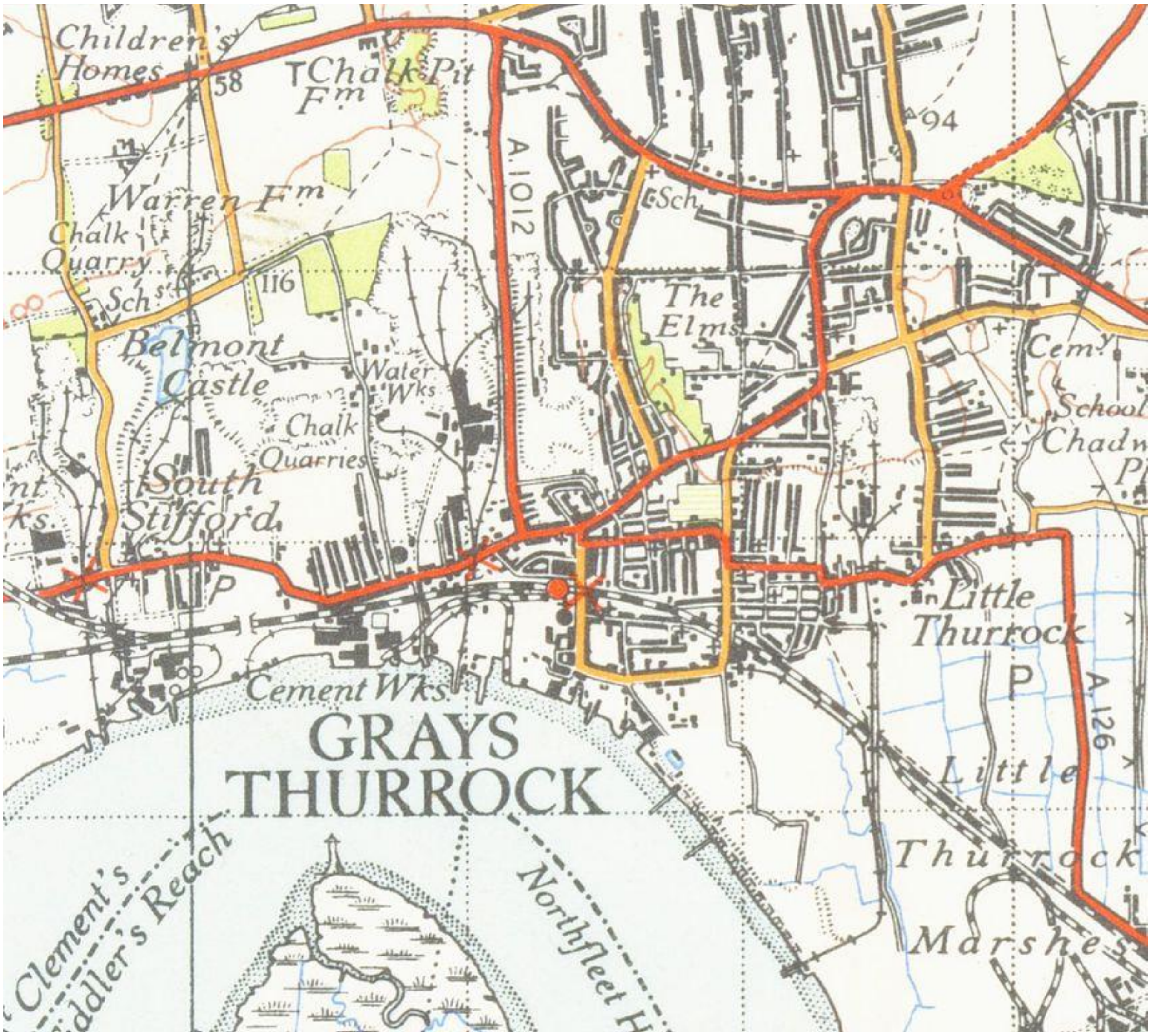
Choropleth map of the world visualising a percentage of population that claims to be vegan. The message this map could convey is limited by the many countries with missing data. Source: Radom1967 / CC BY-SA 4.0

Labeling and Annotation Techniques

In cartography, a **label** is a textual annotation placed on a map to provide additional information about a geographic feature, such as the name of a place, a landmark, or a specific data value. Labels help to clarify the identity or significance of features and are typically positioned near or on the feature they describe. Description and other text data are created and placed on the map only in the final stage of map creation. There are some basic rules for using labels on maps:

- More significant elements are displayed graphically with a more prominent description.
- The descriptive component of the map must be authentic and linguistically correct.
- Standardised names are used.

Placing the labels correctly on a map is crucial: The labels must not mutually overlap, labels cannot overlap map symbols (or vice versa) and there must be a clear distinction between the label and the map symbols (letter O vs. circle marker, letter I vs. vertical lines etc.). Ensuring this involves strategically placing text labels, removing redundant information, adjusting font sizes and ensuring that labels do not overlap or obstruct important map features. The goal is to create a balanced map where the text enhances the understanding of the map without overwhelming the viewer. The process of reducing unnecessary or excessive labels and annotations to improve the map's readability and visual clarity is called **decluttering**.

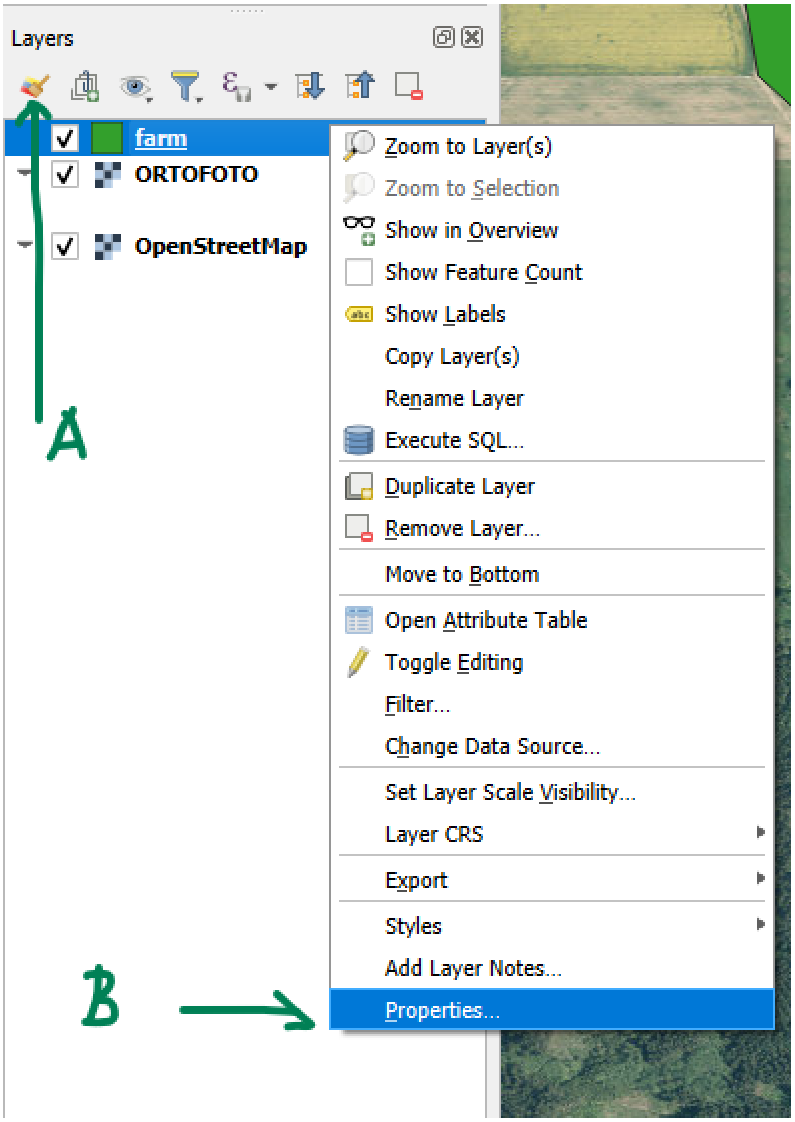


The one inch to the mile scale topographic map by Ordnance Survey from 1946 with carefully placed labels of places.

Source for this chapter: ČERBA, Otakar. Texty na mapách. Department of Geomatics, University of West Bohemia in Pilsen. 2018, CC-BY-NC-SA.

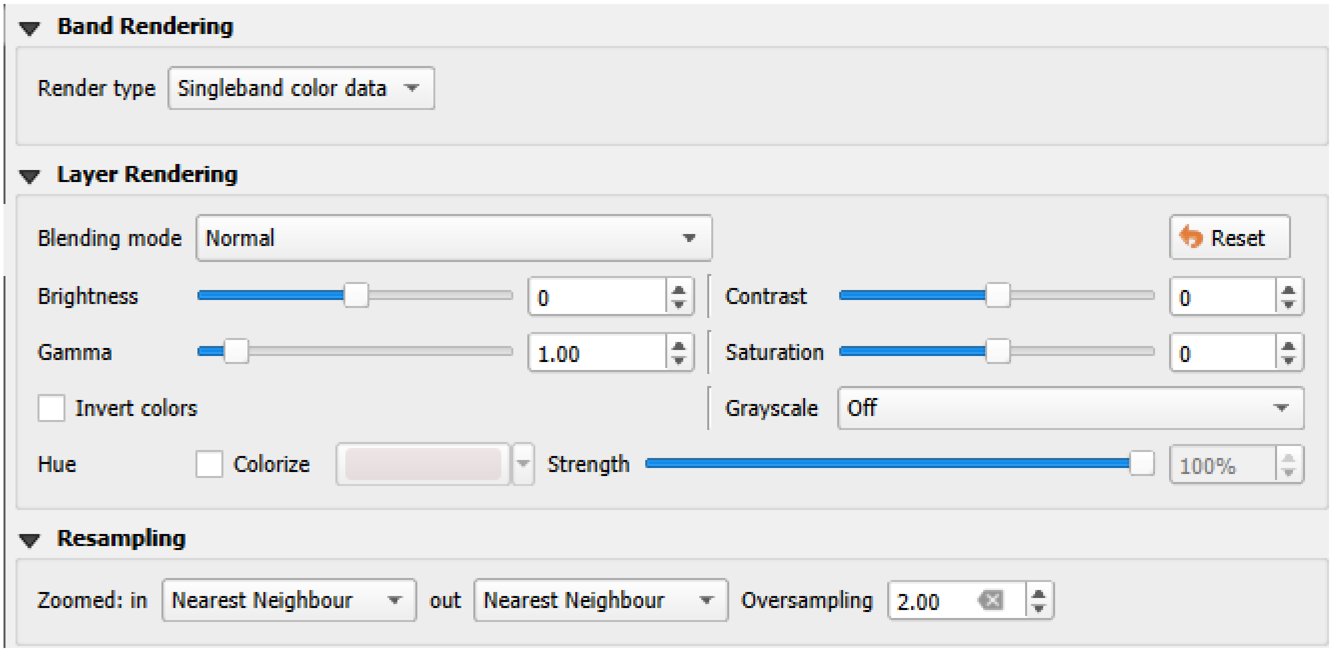
Creating map symbology in QGIS

QGIS provides many ways to modify the symbology of layers, which can be performed by various workflows. One way to access the layer's symbology is opening the Layer Styling panel. Another option is to work with the "Symbology" tab from the layer's Properties.



A button to open the Layer Styling panel (A) and a location of the layer's Properties window.

For raster layers, the “Symbology” tab offers only a limited set of options like adjusting the brightness of the image, or setting the resampling method. For these layers, there is an additional tab “Transparency”, for setting the layer’s transparency (opacity).



Band Rendering

Render type: Singleband color data

Layer Rendering

Blending mode: Normal

Brightness: 0

Contrast: 0

Gamma: 1.00

Saturation: 0

☐ Invert colors

Grayscale: Off

Hue: ☐ Colorize

Strength: 100%

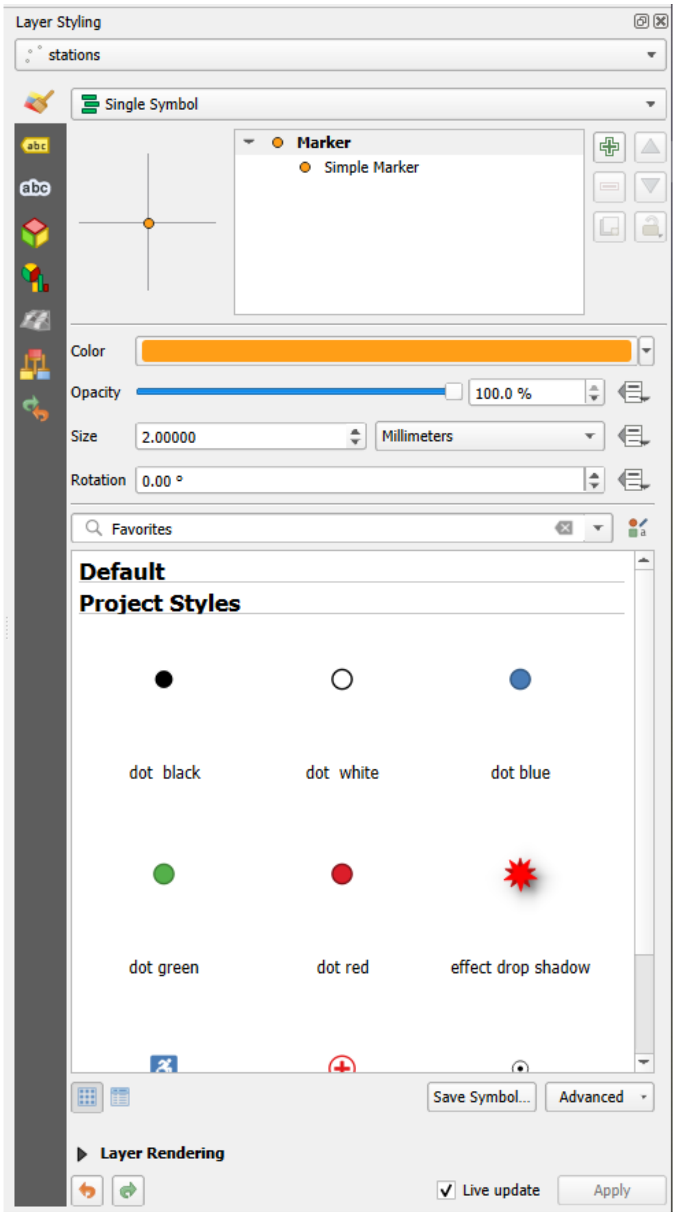
Resampling

Zoomed: in Nearest Neighbour out Nearest Neighbour

Oversampling: 2.00

"Symbology" tab for a raster layer.

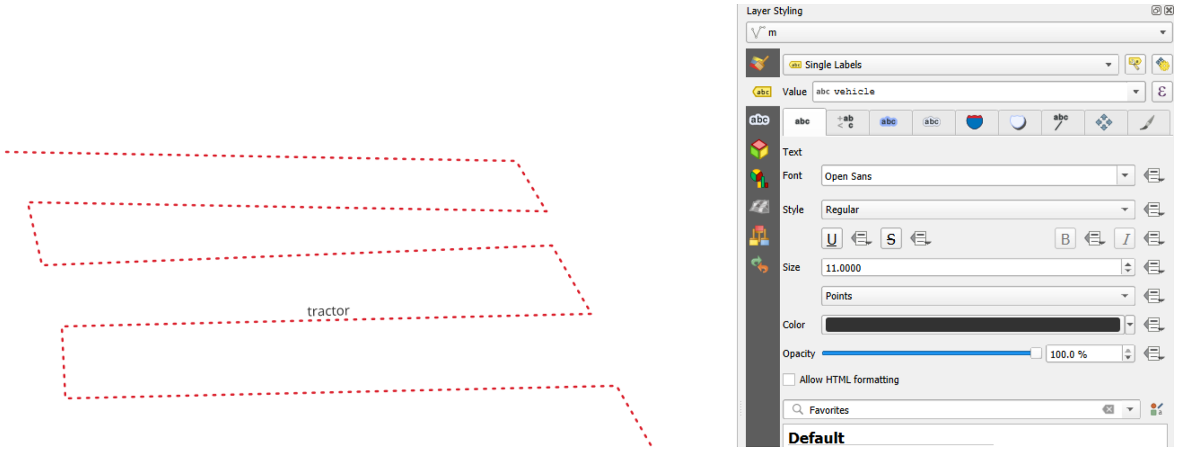
For vector layers, the "Symbology" tab offers a very wide variety of options. Points, lines and polygons can be displayed in a single colour, which is the simplest case, but individual polygons can also have different colours based on the values from the attribute table. The styling options include categorized symbols, graduated colours, rule-based styling etc. Pre-defined styles can be selected from the project's defaults or custom symbols can be tailored via composing markers (for points layers), line styles (for lines) and fills (for polygons) together.



Color
Opacity 100.0 %
Size 2.00000 Millimeters
Rotation 0.00 °

Layers Styling panel of a point layer. The features are symbolised with a simple (circle) marker in a single (orange) colour.

Beside the symbols, labels can be also defined for vector layers. These can be based on a single attribute from the attribute table or composed from multiple attributes based on a set of rules. Many options for the text styling and label placement are also available.



Layer Styling

m

Single Labels

Value: abc vehicle

Text

Font: Open Sans

Style: Regular

Size: 11.0000

Points

Opacity: 100.0 %

☐ Allow HTML formatting

Favorites

Default

A vector (line) layer with labelling set in Layer Styling panel to "Single Labels", showing the name of the vehicle along its path, and how it is displayed in the map canvas.

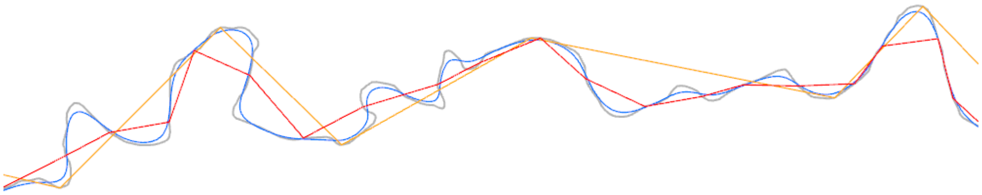
Cartographic Visualization Techniques II

Generalisation Rules

Generalisation in cartography relates not only to the creation of map symbols themselves, but it means a whole process of simplifying or reducing the detail of geographic features, in order to make the map more legible and easier to understand. The whole world doesn't really fit on paper or screen. We just have to choose the important elements – important not to the map creator, but to whoever reads the map.

Common generalisation techniques include:

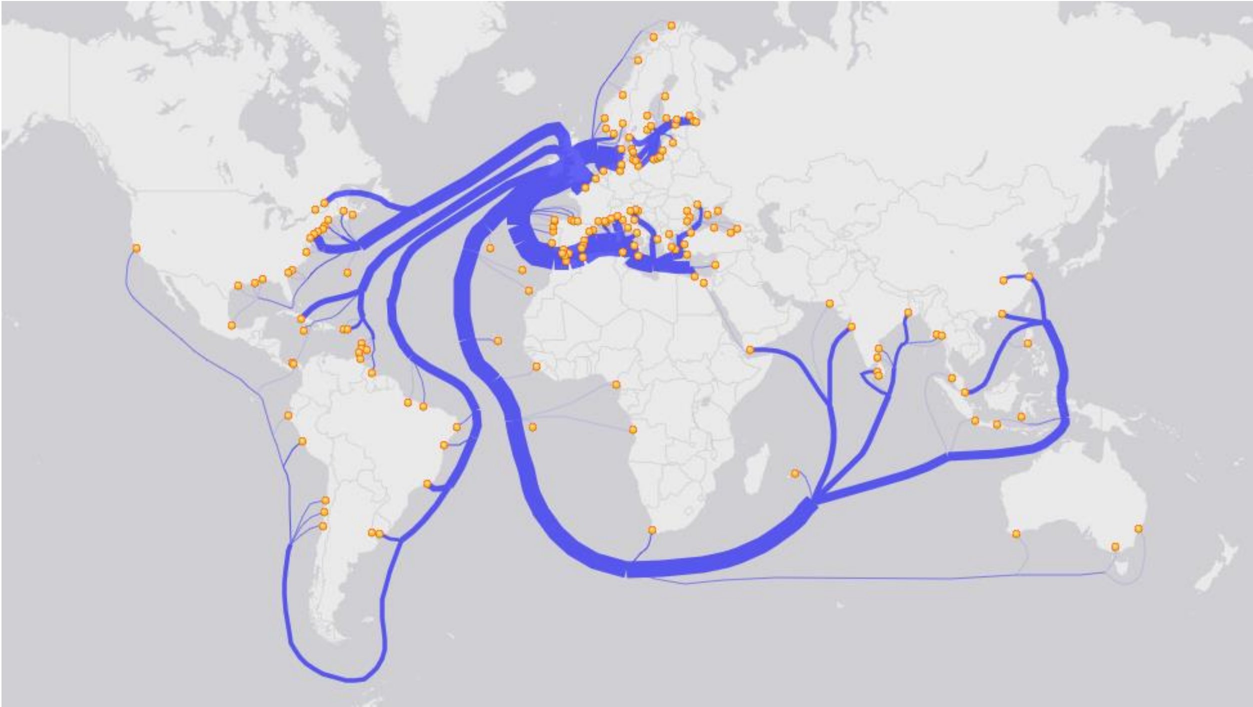
- **Simplification**: Reducing the complexity of shapes, such as smoothing jagged coastlines or straightening curved roads, to make them easier to interpret.
- **Aggregation**: Combining smaller features into larger ones, like grouping individual buildings into a single building block or merging small rivers into a larger waterbody.
- **Selection**: Omitting less important or smaller features, such as removing minor roads or small streams, to focus attention on more significant elements.
- **Exaggeration**: Increasing the size or prominence of features to enhance visibility, such as making a major river wider to make it stand out on a map.
- **Displacement**: Moving map features slightly to prevent overlap or improve readability, such as relocating labels or symbols to avoid clashing with other elements.
- **Categorisation**: Grouping features into categories or classes, such as grouping areas into different land-use types or population ranges and then representing them with a uniform symbol or colour.



Original line in grey colour. Blue, red and orange lines are results of different line simplification algorithms. Source: Bplewe / CC BY-SA 4.0

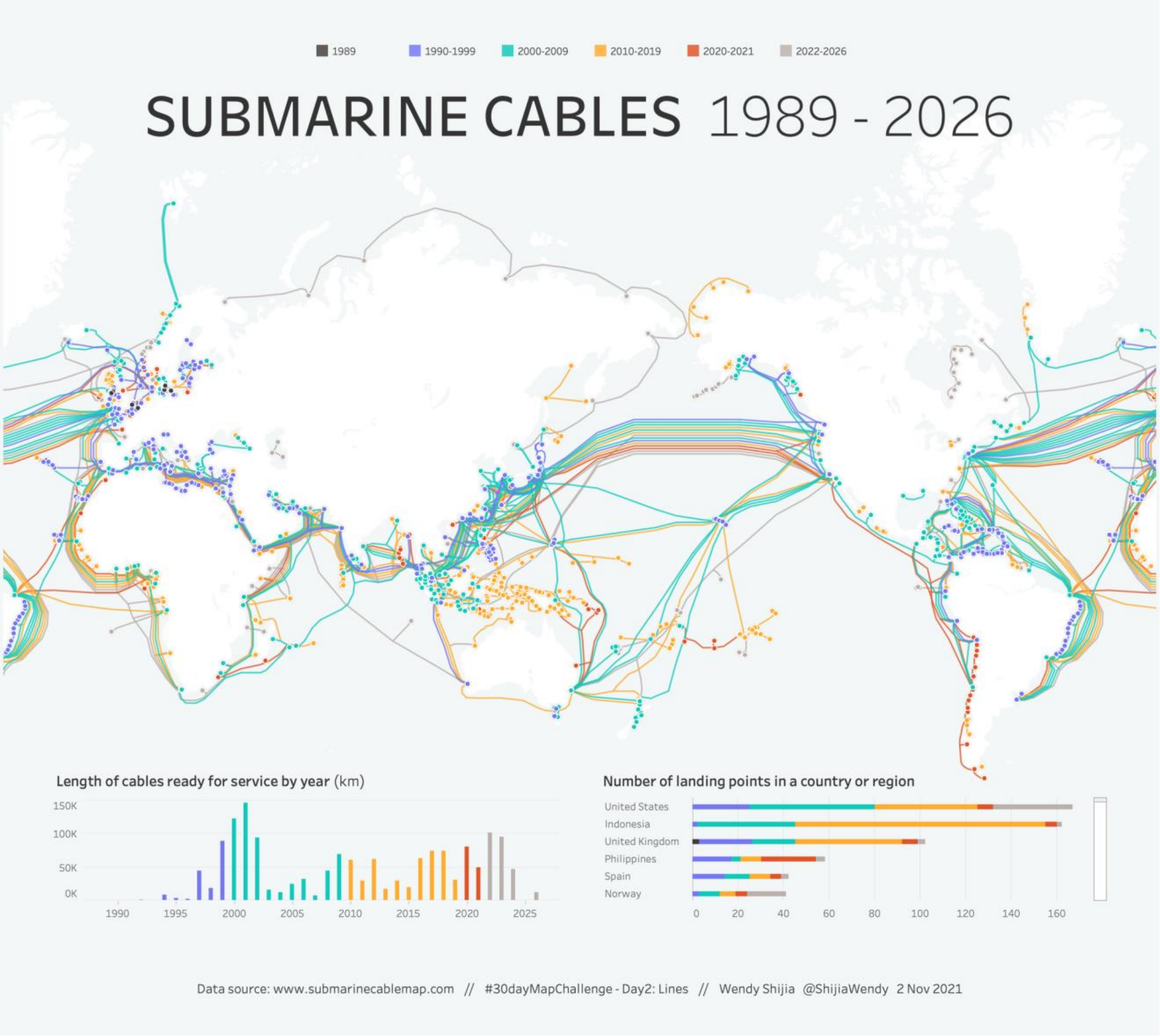
Proportional Symbol Maps

We have already described choropleth maps, where geographic areas are filled with colours of varying intensity or shading or with varying hatch patterns to represent values of a **quantitative spatial data**. Proportional symbols maps use differently sized symbols (points or lines) at specific locations to represent the magnitude of data tied to the related points, lines or areas. In the course "Mapping Fundamentals", *Charles Joseph Minard*'s map of Napoleon's march against Russia was mentioned, which is a great example of **proportional lines** map.



Proportional lines map, also known as flow map, showing English Coal Exports in 1864. Source: https://gisgeography.com/flow-maps/

A **graduated symbols map** is a form or proportional symbols map that represents quantitative data using symbols (such as circles, squares or other shapes) of different sizes. In contrast to proportional points map, in graduated symbols map, the sizes of symbols are grouped into **discrete classes** rather than scaled proportionally. Each class corresponds to a range of data values, and symbols of the same size represent values within the same range. For example, a graduated symbols map might use small, medium, and large circles to represent cities with low, medium, and high populations, respectively. This approach simplifies interpretation while still conveying relative differences in data.


SUBMARINE CABLES 1989 - 2026

Length of cables ready for service by year (km)

Number of landing points in a country or region

Data source: www.submarinecablemap.com // #30dayMapChallenge - Day2: Lines // Wendy Shijia @ShijiaWendy 2 Nov 2021

Submarine cables differentiated by colour based on their age. A variant of a map with graduated lines (although the lines are varying in colour instead of thickness). Source: Wendy Shijia Wang, 2021, https://wendyshijia.notion.site/Wendy-Shijia-s-Dataviz-Archive-6eea22aa2ca44198a06f329724204591

Both proportional symbols and graduated symbols maps are great to communicate a single quantitative variable. Chart maps integrate multiple data dimensions into a single visual representation in the form of charts, such as pie charts, bar charts or other graphical representations known from statistics. These maps visually communicate complex datasets by presenting proportions, comparisons, or distributions of multiple variables directly on the map. For example, a chart map might use pie charts at city locations to show the relative proportions of energy sources (e.g. coal, solar, wind) used in each area, or bar graphs to depict annual rainfall totals over several years.

TILLID I VERDENSKLASSE

De nordiske lande ligger i top, både når det gælder tillid til andre mennesker, til politikere og til retssystemet. Måske er tillid det bedste kort, vi har på hånden, når vi skal møde fremtidens udfordringer.

norden
Nordisk Ministerråd

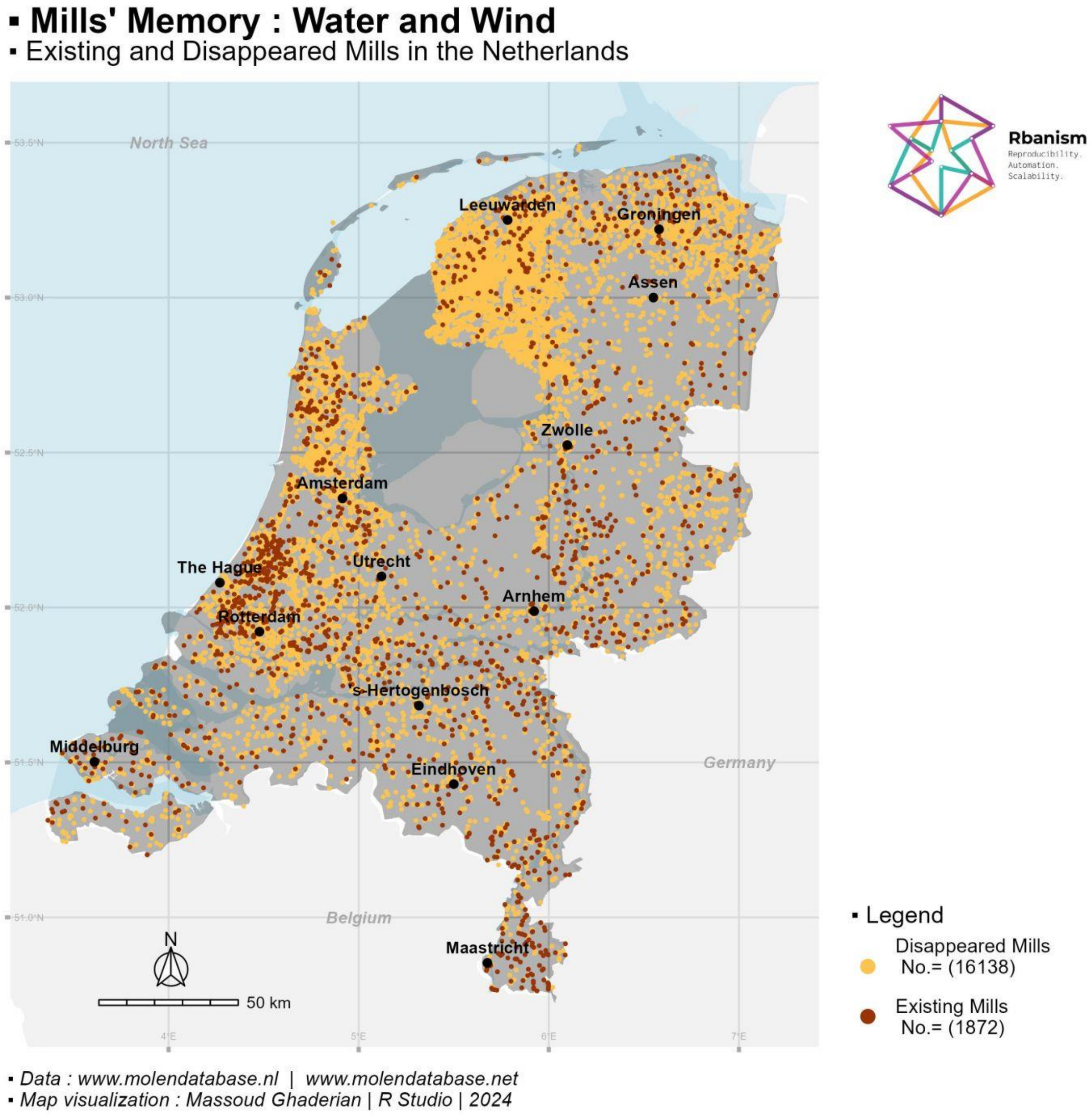
Kilde: European social survey (2010)

Læs mere her: **www.norden.org/vaelfaerd**

Map of Europe with bar charts on selected countries displaying the ratio of trust among the society. It is divided into trust in justice, trust in politics and trust in the other people. Source: Ferdio, https://www.ferdio.com/en/nordic

Dot Maps

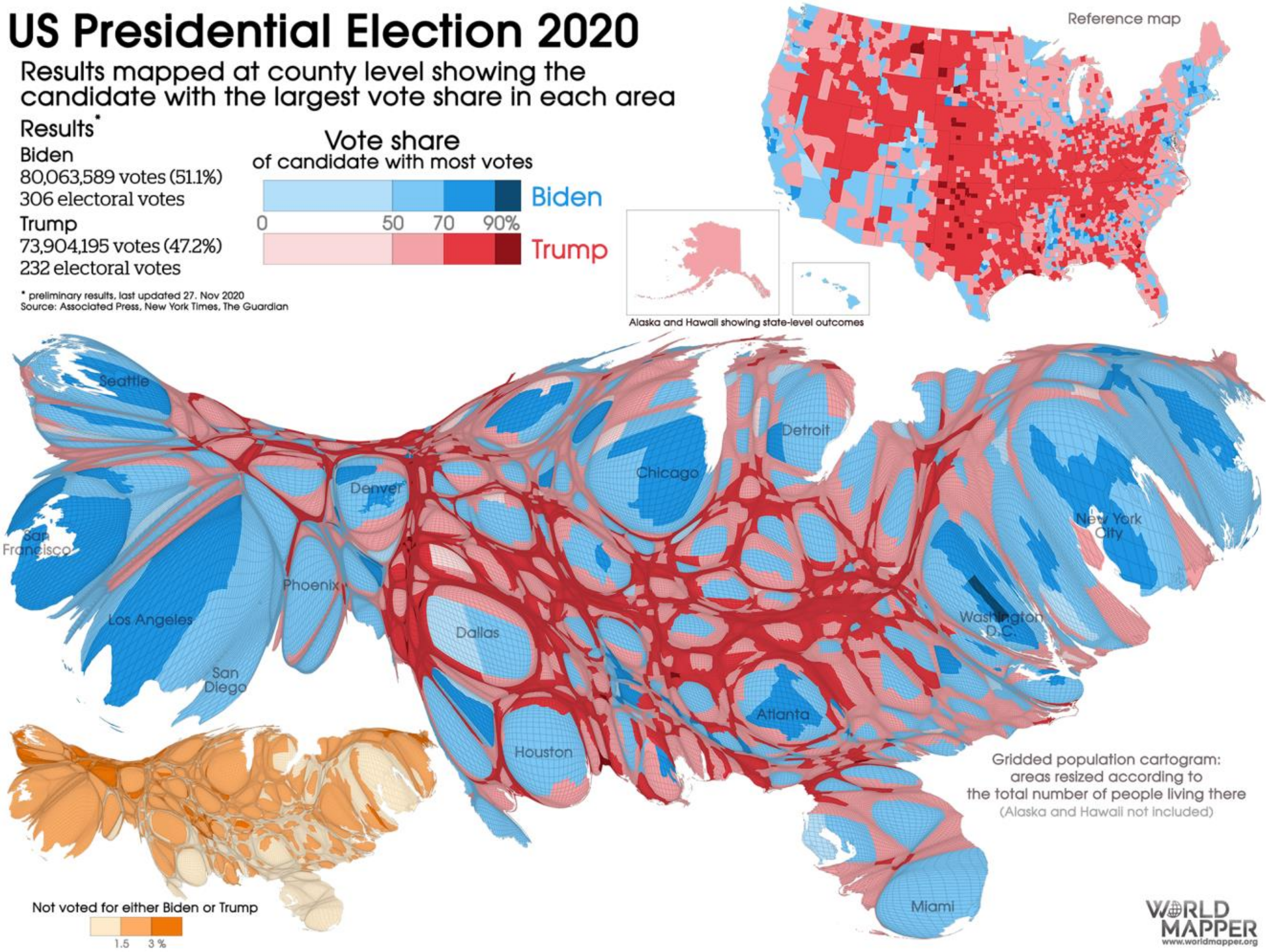
In the course “Mapping Fundamentals”, *John Snow*’s cholera outbreak map with dots was mentioned as setting the basis for modern epidemiology. Dot maps are a type of thematic map that uses dots to represent the spatial distribution of a variable, with each dot corresponding to a specific quantity of the data being mapped. One dot can represent one piece of the depicted phenomena, but it can also be valued as 10, 1 thousand, 1 million or any ratio of pieces. Dot maps are particularly effective for showing density or concentration, such as population distribution, agricultural production, or the location of specific events. The placement of dots can be either exact, reflecting precise locations of data points, or approximate, spread across an area to represent aggregate data. Dot maps differ from other thematic maps, like choropleth maps, by emphasizing individual occurrences or distributions rather than summarizing data over predefined regions, offering a more granular and visually intuitive representation of patterns.



A map of the Netherlands showing windmills and watermills. The colour distinguishes if the mill still exists or if it has already vanished. Each mill is represented with a single dot. Source: Massoud Ghaderian, 2024, via LinkedIn

Cartograms

Until now, all cartographic visualisation techniques described were respecting the boundaries of geographic shapes in which the phenomenon is depicted. This is not the case in the cartogram method. A **cartogram** is a type of thematic map in which the size of geographic areas is distorted or reshaped to represent a specific variable, rather than reflecting their actual geographic size. The distortion is proportional to the data being represented, such as population, income or election results. Cartograms help to highlight the relationship between spatial distribution and the variable being mapped, often providing a more intuitive understanding of the data.



Comparison of US Presidential elections 2020 depicted by different visualisation methods. Top right – traditional choropleth map with county level data, middle – cartogram with radial distortion and area size proportional to population of the state. Source: https://worldmapper.org/us-presidential-election-2020/

Common Cartographic Mistakes

Creating accurate and effective maps requires a balance of technical skill, attention to detail, and a clear understanding of cartographic principles. However, map makers—not only those with limited experience or training—often make errors that can distort or misrepresent the data being presented. These mistakes, whether intentional or unintentional, can lead to confusion, misinterpretation, or even manipulation of information, undermining the map’s purpose. A great publication about common cartographic mistakes is *How to Lie With Maps* by *Mark Monmonier*. Frequent mistakes done by map makers include but are not limited to:

- **Excessive use of colours**: Using too many colours or choosing colours that are not intuitively associated with the data, leading to confusion.

- **Inappropriate colour gradients**: Applying a gradient scale that does not align logically with the data (e.g. using red to represent low values and green for high values in a context where red indicates danger).
- **Improper use of proportional symbols**: Using symbols that are not accurately scaled to the data values or exaggerating size differences.
- **Arbitrary classification breaks**: Choosing arbitrary or unequal class intervals for data in choropleth maps, which can skew perceptions of the data.
- **Lack of a legend**: Failing to include a clear and accurate legend, leaving the viewer unable to interpret the symbols, colours or scales.
- **Overcomplicating the map**: Including too much data or unnecessary layers, overwhelming the user and obscuring the main message.
- **Simplifying too much**: Removing critical details or context, which can mislead viewers about the nature of the data.
- **Distorting areas with inappropriate projections**: Using map projections that distort size or shape, such as Mercator for area-based analyses, without addressing the distortion's impact.
- **Unequal spatial units**: Comparing data across regions of vastly different sizes without normalizing the data (e.g. population counts instead of density).
- **Cherry-picking data**: Selecting data that supports a particular narrative while ignoring contradictory information.
- **Misleading symbology**: Deliberately using colours, symbols or scales to overemphasize or understate specific areas or trends.
- **Using outdated or inaccurate data**: Displaying information that is no longer relevant or has errors.
- **Ignoring data source credibility**: Failing to use reputable sources or verify data accuracy.

Creating thematic maps in QGIS

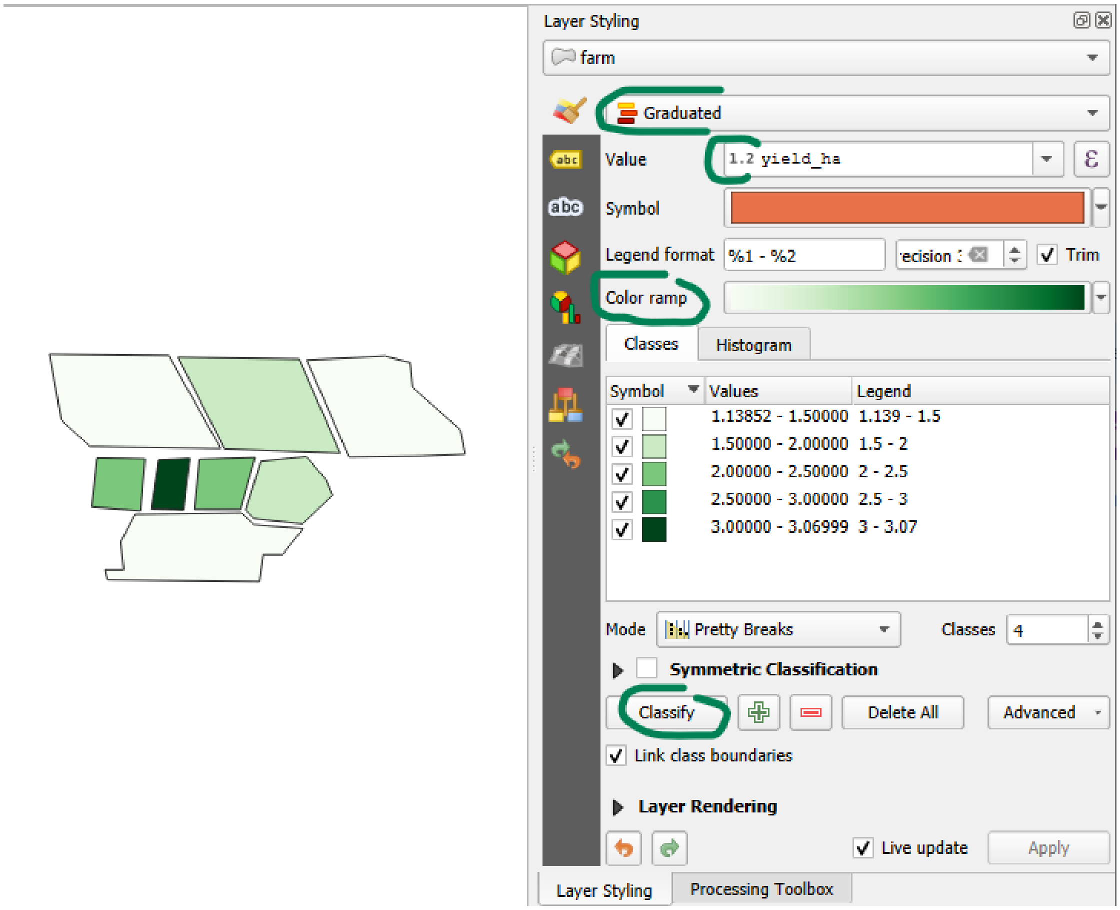
Refer to chapter *Cartographic Visualization Techniques I* to understand how a symbology of a layer can be adjusted in QGIS.

Layer Styling panel in QGIS is very suitable for preparation of a thematic map. Yet having the appropriate data to an intended purpose is crucial. If the geodata does not include the necessary information in its attribute table or if the attributes are not in a usable form, it will be likely impossible to create a desired map or the map will convey a misleading message.

When a vector layer with polygons is present and the layer has an attribute which is **quantitative**, then such a map layer is ideal to represent as a choropleth map. A quantitative attribute can be an amount of spray applied, number of livestock on pasture or a yield of a field. First, it is very important to verify that the values in the attribute column are relative to the size of the polygons. If the values are not relative, they need to be *normalised* first. Normalised values are “spray applied per square metre”, “livestock per acre” or “yield per hectare”. The calculation of normalised values can be done by dividing the absolute value by the area of the polygon. The normalised value is usually saved as a new attribute column. Displaying absolute values would be misleading as larger areas usually hold larger amounts of the phenomena (crop, livestock, etc.).

A polygon layer with a normalised quantitative attribute can be styled as a choropleth map in the Layer Styling panel in QGIS. In the panel, the symbology must be changed from “Single Symbol” to

“**Graduated**”. Then the attribute column and an adequate color ramp must be selected. When the attribute column is classified, the colour of polygons in the map shall change. Sometimes it is also beneficial to change the classification method (Pretty Breaks, Equal Interval, Standard Deviation, etc.) or the number of classes to create, depending on the actual values of the data.



Value: 1.2 yield_ha

Legend format: %1 - %2 ☑ Trim

Symbol	Values	Legend
☑	1.13852 - 1.50000	1.139 - 1.5
☑	1.50000 - 2.00000	1.5 - 2
☑	2.00000 - 2.50000	2 - 2.5
☑	2.50000 - 3.00000	2.5 - 3
☑	3.00000 - 3.06999	3 - 3.07

Mode: Pretty Breaks Classes: 4

☑ Link class boundaries

☑ Live update

Creating a choropleth map with “Graduated” symbols based on the attribute column “yield_ha”, classified into 5 classes, each with a distinct shade of green.

Practical Applications of GIS

Training Session: Using QGIS for Urban Planning

Duration: 3 hours

Objective:
This training session aims to introduce participants to the use of QGIS for urban planning tasks, including data visualization, spatial analysis, and decision-making processes related to urban growth, infrastructure, and zoning. Participants will learn how to leverage QGIS tools to analyze urban spaces and improve urban planning strategies.

Agenda

Introduction to QGIS (30 minutes)

- **Overview of QGIS**: Brief introduction to QGIS interface, tools, and functionalities.
- **Setting up a project**: Demonstrating how to create a new project, load data layers (shapefiles, raster files, etc.), and configure map views.
- **Basic Navigation**: Zooming, panning, and using coordinate reference systems in QGIS.

Session 1: Urban Data Visualization (45 minutes)

- **Importing Urban Data**: How to import GIS data relevant to urban planning, such as zoning maps, land use, transportation infrastructure, and population density.
- **Symbolizing and Styling Data**: Demonstrating how to apply styles (colours, labels, and patterns) to various urban features for clear visualization.
- **Using Aerial Imagery and Basemaps**: Layering and configuring satellite imagery or OpenStreetMap basemaps to support urban analysis.

Session 2: Urban Spatial Analysis (60 minutes)

- **Buffer Analysis for Infrastructure**: How to create buffers around roads, utilities, or parks to analyze their proximity and influence on urban planning decisions.
- **Density Mapping**: Analyzing population or building density in certain areas of a city to identify overcrowded or underdeveloped regions.
- **Land Use Analysis**: Using QGIS tools to overlay land use data with zoning or development plans to identify conflicts or potential areas for growth.
- **Suitability Analysis for New Developments**: Demonstrating the process of creating a suitability model for selecting the best sites for new housing or commercial developments based on factors like proximity to roads, water supply, and green spaces.

Session 3: Scenario Modeling and Planning (30 minutes)

- **Urban Expansion Modeling**: Using tools like raster calculator to simulate future urban growth and understand how changes to infrastructure affect the city.
- **Impact Assessment**: Demonstrating how to model the environmental and social impacts of potential developments using spatial analysis tools (e.g., identifying flood-prone areas for new construction).

Session 4: Sharing and Presenting Results (15 minutes)

- **Creating Layouts**: How to design printable map layouts for reports, including adding titles, legends, scale bars, and north arrows.
- **Exporting Data**: How to export maps and results to formats such as PDF, SVG, or image files.
- **Publishing Web Maps**: Introduction to publishing maps on the web using QGIS and web mapping tools (such as QGIS Server or QField).

Wrap-Up (15 minutes)

- **Q&A Session**: Open floor for questions, clarifications, and feedback.
- **Suggested Resources**: Provide a list of resources, tutorials, and further reading materials for continued learning.

Requirements

- **Software**: QGIS installed on participants' computers (version 3.x or higher).
- **Data**: Sample urban planning data (e.g., shapefiles for zoning, land use, population density, infrastructure, etc.) will be provided prior to the training.
- **Prerequisites**: Basic knowledge of GIS concepts or prior use of GIS software is recommended but not required.

This session will provide a hands-on, practical introduction to using QGIS for urban planning, allowing participants to apply GIS tools to real-world urban scenarios.

Training Session: Using QGIS for Environmental Management

Duration: 3 hours

Objective:
This session will introduce participants to how QGIS can be utilized in environmental management tasks, focusing on data analysis, monitoring, and decision-making processes related to conservation, resource management, and environmental protection. Participants will learn to use QGIS to analyze spatial data, assess environmental impacts, and visualize critical information for effective environmental management.

Agenda

Introduction to QGIS (30 minutes)

- **Overview of QGIS**: Quick introduction to the QGIS interface, basic tools, and key features relevant to environmental management.
- **Setting up a Project**: Creating a new project, importing environmental data layers (e.g., land use, vegetation, water bodies), and configuring map views for analysis.
- **Navigating and Exploring Data**: Techniques for zooming, panning, and exploring the spatial data.

Session 1: Mapping Environmental Data (45 minutes)

- **Importing Environmental Data**: How to load environmental datasets such as vegetation cover, water bodies, forest areas, and pollution levels.
- **Visualizing Environmental Layers**: Demonstrating the process of symbolizing environmental data using colour gradients, transparency, and classifications to enhance interpretation.
- **Using Satellite Imagery**: Layering satellite imagery for detailed analysis of natural resources and environmental features.

Session 2: Spatial Analysis for Environmental Management (60 minutes)

- **Buffer Analysis for Environmental Impact**: Creating buffers around key environmental features like rivers, wetlands, or protected areas to assess potential environmental impacts.
- **Identifying Protected Areas**: Using QGIS to map and analyze conservation zones, national parks, and protected areas to assess their boundaries and connectivity.
- **Suitability Mapping for Conservation**: How to conduct suitability analysis for identifying areas for conservation efforts, like wildlife corridors or potential sites for habitat restoration.
- **Pollution and Environmental Hazard Mapping**: Analyzing and mapping pollution sources such as air quality, industrial emissions, or hazardous waste sites.

Session 3: Environmental Risk Assessment and Modeling (30 minutes)

- **Flood Risk Mapping**: Using digital elevation models (DEMs) to identify flood-prone areas and analyze the potential impact of flooding on ecosystems and human settlements.
- **Erosion Risk Assessment**: Using spatial analysis to assess areas at high risk of soil erosion and land degradation due to human activities or climate change.
- **Climate Change Impacts**: Modeling and visualizing the potential effects of climate change on different environmental factors such as vegetation or water resources.

Session 4: Reporting and Presenting Environmental Data (15 minutes)

- **Creating Maps for Reports**: How to create professional, clear, and informative maps for environmental management reports.
- **Adding Layouts and Annotations**: Demonstrating the process of adding titles, legends, scale bars, and other map elements to produce an effective final product.
- **Exporting and Sharing Data**: Exporting maps to different formats (PDF, SVG, image files) and sharing results with stakeholders or decision-makers.

Wrap-Up (15 minutes)

- **Q&A Session**: Open forum for questions, clarifications, and discussion of real-world applications.
- **Further Resources**: Providing additional resources, tutorials, and links for further learning in GIS and environmental management.

Requirements

- **Software**: QGIS installed on participants' computers (version 3.x or higher).

- **Data**: Sample environmental datasets will be provided, including land use, vegetation, water bodies, and pollution data.
- **Prerequisites**: A basic understanding of GIS concepts will be helpful, though not required.

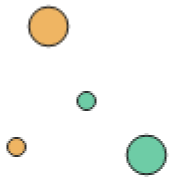
This session will equip participants with the skills to use QGIS for effective environmental management, focusing on spatial analysis, monitoring, and decision-making to support sustainability and conservation efforts.

Course Final Quiz

1. Which description explains the best what a **Geographic Information System** (GIS) is?
    a. data representing features or phenomena related to the Earth
    b. computer-based system to analyse and present spatial data
    c. the process of surveying of geographical phenomena and creating a map
2. Which statements are valid for a **raster data** model?
    a. …is based on a grid of square cells, often called pixels
    b. …is also suitable to represent objects in three dimensions using cube cells (voxels)
    c. …the geometry and characteristics of the described elements is modelled using *features*
    d. …digital elevation models (DEMs) are a typical case of raster layers
3. Which process can be described as "**redrawing features into a vector layer from a raster layer**"?
    a. rasterisation
    b. generalisation
    c. vectorisation
    d. querying
4. Which language is commonly used for **selecting data** from an attribute table?
    a. British English
    b. Python
    c. Structured Query Language
    d. Hypertext Markup Language
5. Choose which advantages bring the usage of **spatial databases**?
    a. Databases can store and manage vast amounts of data in one place, eliminating redundancy.
    b. Databases ensure data consistency and provide access control mechanisms to secure sensitive information.
    c. Databases do not require any setup and are easy to configure and maintain.
    d. Databases are easy to transfer from one place to another, making them ideal for sharing data.
6. Select valid examples of **qualitative data**:
    a. soil type
    b. amount of spray applied
    c. livestock per hectare
    d. land cover
7. Select valid examples of **quantitative data**:
    a. soil type
    b. amount of spray applied

    c. livestock per hectare
    d. land cover

8. Select visual variables used to distinguish symbols in the example below:



    a. colour hue
    b. size
    c. colour lightness
    d. orientation

9. Select what is possible to do with a QGIS:
    a. Load geodata into map project
    b. Save map project
    c. Connect to a WMS service
    d. Change layer symbology

10. Select what is possible to do with a HSLayers-based WebGIS:
    a. Load geodata into map canvas
    b. Save map composition
    c. Connect to a WMS service
    d. Change layer symbology