MAPPING TOOLS FOR SUSTAINABLE AGRICULTURE AND FORESTRY

PRACTICAL GUIDE TO USE

September 2023

Foreword

This booklet has been produced as part of the joint activity of the ProSICD project and the GIZ Sector Programme for Sustainable Agricultural Supply Chains and Standards (INA). Designed by the geomatics experts of the company ACTUM DEV, this booklet offers technical and practical solutions for sectors working in the development and management of land and ecosystems. Specifically, it was produced taking into account the needs of cooperatives, regional councils, commodity-related councils, and technical government entities, such as ministries of territory, agriculture, water, forests, planning, etc. As such, this manual addresses the following pillars:

- Good practices for field data collection and storage ,
- Learning and mastering the use of cartographic software for data management and processing,
- Solutions to specific needs encountered in the field,
- Decision-making tools in the face of sustainability issues (especially deforestation).

This booklet was made possible thanks to:

• ProSICD (Sustainable Cocoa Initiative Support Programme), co-financed by the European Union and the Federal Ministry for Economic Cooperation and Development (BMZ) through the Agrichains project;

• The GIZ Sector Programme for Sustainable Agricultural Supply Chains and Standards (INA,) which is a transnational project that focuses on agricultural commodities such as coffee, cocoa, bananas, soybeans, rubber, palm oil and cotton;

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0. PRESENTATION OF THE TRAINING

0.1. Contextualization of training

An example from Côte d'Ivoire

Mr. Yapi Gaston is a cocoa producer with 10 hectares of plot. To secure the plot that he obtained from his father, he decides to participate in the Land Policy Improvement Program initiated by the State (PAMOFOR) in order to obtain a Land Certificate (LC). During validation, his file is put on hold because part of his plot would end up in classified forest. He therefore seeks help from the water and forestry department which is technically unable to answer him. However, it guides him to the forest registry office in Abidjan, which gives him a technical file confirming unfortunately that his plot is partly in a classified forest.

Mr. Yapi also discovers that because of that area of his plot in the classified forest, his production could not be sold by his or any other cooperative because of new regulations such as the EU Deforestation Regulation (EUDR). This situation is not isolated, as it affects several other parcels of members of the cooperative. The cooperative's revenue is threatened to take a big hit.

With all the national and international regulations, buyers demand cooperatives to prove that their cocoa does not come from deforested areas or classified forests (through provision of polygons) under penalty of not being able to sell their production.

Under pressure, the CEO of the cooperative calls a consultancy company for an audit of their plot, but the cost of this activity is very high given the limited time. This situation could have been avoided beforehand with good data collection by field agents equipped with GPS devices. This scenario is one case among many that all actors in the agricultural and land sector could face (producers, cooperatives, technical agents of water and forestry, agents of municipalities and regional councils, commodity boards such as the Ivorian Conseil Café Cacao, etc...).

This manual is made to provide a technical foundation to address this kind of scenario. In summary, this manual provides information on:

- How to collect quality data in the field;
- How to process field data and produce coherent and useful databases to anticipate the aforementioned problems;
- How to continuously fill in databases and keep them up to date;

- How to produce maps easily presenting the data collected and facilitate the decision of the hierarchy.

0.2. Challenges of cooperatives

This training addresses several challenges that cooperatives may encounter. Through this training, cooperatives will be better able to:

- Monitor and manage the data of members' farms;
- Identify problematic farms and provide effective solutions for the benefit of the cooperative;
- Make better estimates of the overall production (advance knowledge and control of the cooperative's turnover);
- Better plan and deploy activities during campaigns;
- Anticipate land issues and help producers;
- Better access finance;
- Easier market quality products .

0.3. Training objective

The objective of this training is to strengthen the capacities of cooperatives and other actors to use GPS and QGIS, as well as how to read maps and use them in the sustainable management of agricultural, forestry and environmental activities. Specifically, this training will help to:

- Explain the basics of geographic information;
- Work with GPS data in QGIS;
- Collect geographic data in the field;
- Use GPS and mobile tools with QGIS;
- Implement thematic mapping;
- Modify geographic data and create maps

0.4. Target

This training document is published for technical officers in the agricultural, forestry and land use planning sectors. It is specifically designed for:

- Agricultural cooperatives;
- Agents of ministries;
- Technical sustainability officers of regional councils

0.5. Disclaimer

This manual was designed in 2023 with the technologies available at the time. The software packages used (QGIS installers) are available from this page https://www.qgis.org. The used version was QGIS 3.26.3 'Buenos Aires', released on 09.09.2022. The stable long-term release version at the time of conception is QGIS 3.28.10 'Firenze'. QGIS is available for Windows, macOS, Linux, Android and iOS.

I- MODULE 1: DEFINITION AND PRINCIPLES OF CARTOGRAPHY

1.1. Purpose of the module

The aim of this module is to provide participants with a basic understanding of the entire training program, covering the concepts and fundamentals required to understand the following modules. It provides definitions and explains principles.

1.2. Definition and principle of cartography

Cartography is a set of methods and techniques for making a map. The purpose of a map is the graphic and geometric representation of the entities and phenomena observed in an area, resulting from the analysis of qualitative and/or quantitative data.

The creation of a map requires several stages:

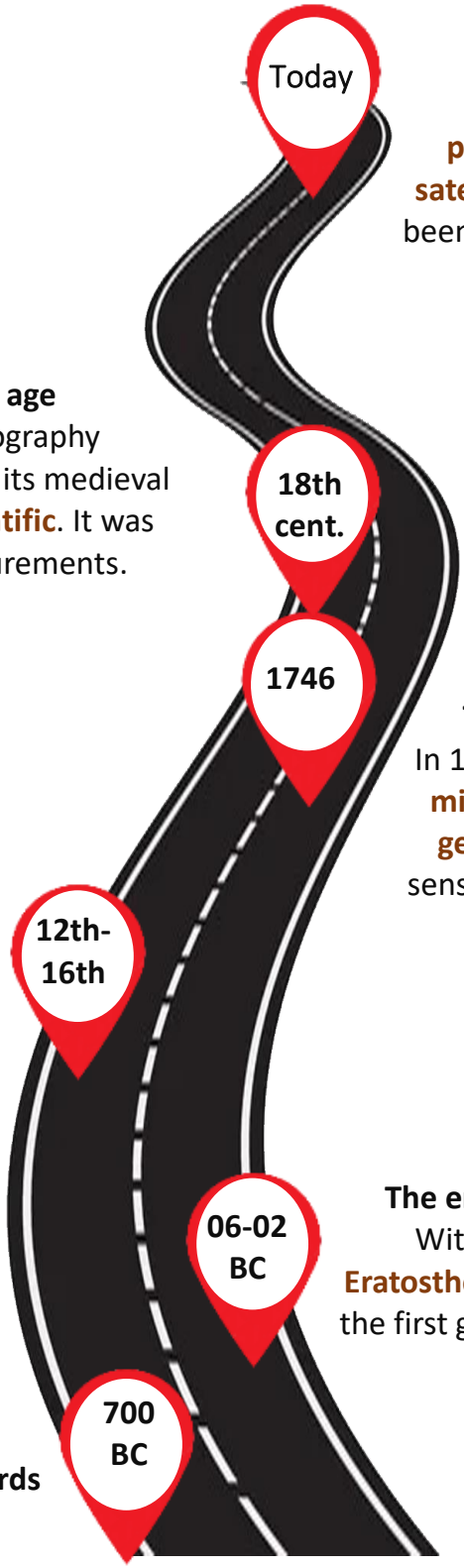
1. Research and/or data production;
2. Data analysis and quality control;
3. Storage in a secure database if the data is sensitive;
4. Drawing the map, following certain graphic design rules.

The main principle of cartography is the representation of data on a reduced medium, representing a space that is generally considered to be real. The objective of a map is to represent complex phenomena (political, economic, social, etc.) in a concise and effective way.

1.3. History of Cartography

The history of cartography began with the desire to see the world as a whole. This vision took shape with the technical advances that made it possible to obtain a more accurate image of the earth.

The birth of scientific cartography is generally attributed to Ptolemy, a Greek astronomer, mathematician and geographer from the 2nd century AD, who compiled the knowledge available in geography at the time.



Modern maps
With the arrival of **aerial photography**, **computers** and **satellite imagery**, cartography has been **revolutionized** and is reaching into **all fields**.

Maps in the scientific age
In the 18th century, cartography definitively moved away from its medieval roots and became truly **scientific**. It was the century of exact measurements.

The beginning of thematic maps
In 1746, Jean-Etienne Guettard drew up **mineralogical maps** (**precursor of the geological map**). These maps were a sensation and demonstrated a new spirit of research.

Exploration maps
Based on the work of Ptolemy, the geographic explorer **Idrisi** (12th century) draws up a map that aims to discover the world.

The era of geographic coordinates
With the work of **Ptolemy** and **Eratosthenes** it was possible to calculate the first geographical coordinates around the year 3 BC.

The Era of Clay Disc Cards
engraved by scribes.

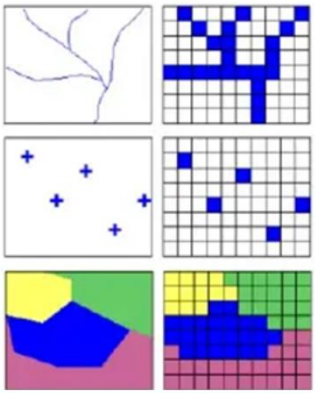
Graphic based on Minelle, 1992

1.4. Definition of concepts

1.4.1. Rasters and vectors

There are 2 main types of geographic data in GIS: "Rasters" and "Vectors":

- A Raster corresponds to grids composed of cells (like an "image" composed of pixels). Each cell contains a value that often represents a geographical phenomenon, for example, altitude or land cover. It can be a scanned map, an aerial photograph, a satellite image, a digital photo, or a DEM (Digital Elevation Model)
- Vectors are composed of points, lines or polygons. The most common vector file format in GIS is the "shapefile" format and therefore the name "shapefile" is often used as a synonym for "vector file".

Vector	Matrix or Raster	Real-life example
		**Linear data** : rivers, routes,...
		Point data : Trees, weather stations, GPS points, ...
		Polygon data : administra-tive boundaries (country borders, commune boun-daries, etc.), nature parks, lakes,...

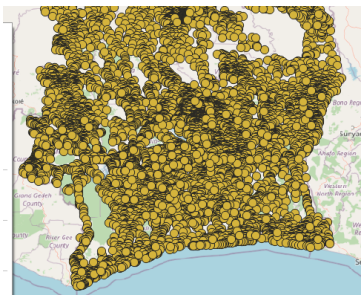
NB: GPS data is therefore "vector" data.

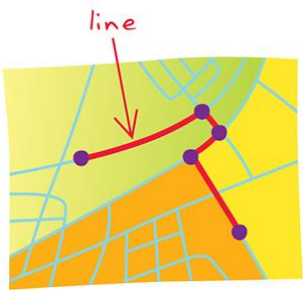
1.4.2. Cartographic forms

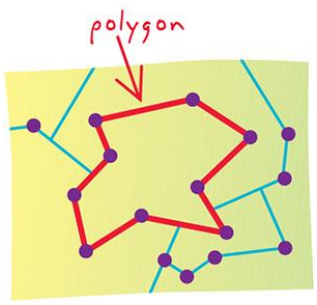
Point: a geodetic feature defined by a pair of x,y coordinates.

Line: a shape defined by a connected series of points. A line can be straight or curved.

Polygon: a closed shape defined by a series of points.







1.4.3. Scale

Scale refers to the ratio between a real distance, measured on the Earth's surface and that of its representation on a map. Since it is a ratio, the scale will be "small" when the denominator is large and conversely "large" when the denominator is small (e.g., from 1/1,000,000 to 1/25,000).

1.5. Key advantages of digital mapping and fields of application

Unlike conventional mapping, the new digital mapping is characterized by:

- Its powerful storage capacity and variety of print formats;
- Its ability to modify and represent large volumes of geospatial data;
- Its flexibility to adjust scale and disseminate geospatial data;
- The possibility to modify an old map, remake it and personalize it
- Its ability to do the layouting of the map.

Nowadays cartography is used in several fields such as:

- Mineral prospecting: to search for minerals, collect prospecting data, process them and represent them in geological maps;
- Risk prevention and management: through the creation of databases of critical facilities, such as hospitals, ambulances, fire stations, police stations, schools etc. Similarly, disaster maps can be prepared to show areas at risk as well as potential disaster impact areas;
- Water management and geospatial representation of measured water variables (hydrology);
- Urban planning (land registry, roads, road network management): contributes to site selection, land balance analysis, land use and transport modelling, identification of planning action areas and impact assessments;
- Urban transport planning and route optimization: provides information on the transport infrastructure cycle, and enables complex systems to be planned, monitored and managed more efficiently;
- Forest development, harvest management, silviculture: mapping of flammables and weather conditions and assessment of fire danger, which can have a negative influence on vegetation cover, animals, plants, soil, water flow, air

quality, microclimate and general climate;

- Animal population movement;
- Telecommunication: Assistance in the choice of antenna mounting locations (e.g., in remote areas);
- Tourism: Management of tourist infrastructure and routes;
- Customer acquisition and management .

1.6. What to remember

Cartography is a way of analysing, defining and interpreting geographic space and the elements within it. It provides information about element or phenomena in given parts of the world.

II- MODULE 2: PRINCIPLES AND OPERATION OF THE GPS SYSTEM

2.1. Purpose of the module

Have you ever encountered the situation that when you take GPS points of two neighbouring plots, the polygon boundaries overlap?

Have you ever found that you've taken points in the field but, once back at the office, they've been recorded or observed miles away from your initial position?

If so, this module will enable you to understand the causes in order to anticipate and avoid these errors on your next field mission. It will give you the essential understanding how GPS works, so that you can optimize data collection and obtain good-quality data. An important word will occur several times in this module: "accuracy". Our approach is to discover the history of GPS and to bring out the essential information for using your GPS device with the various existing systems.

2.2. History of GPS

The Global Positioning System (GPS) is a satellite-based positioning system owned by the US government. In the context of the arms race and emerging new technologies, it was set up by the US Department of Defense for military purposes from 1973 onwards.

Initially, the aim was to enable soldiers to locate and orientate themselves accurately in order to gain a strategic advantage over the enemy.

The first satellite was launched in 1978. In 1983, following the deaths of 269 passengers in the Korean Air Lines flight 007 incident, President Ronald Reagan proposed that GPS technology should be made available to civilians free of charge once it was operational. A second series of satellites was launched in 1989 to build up a sufficient fleet.

In 1995, the deployment of the 24 operational satellites (plus 4 in reserve) was completed and the system became operational. The number of satellites available meant that GPS could be used around the world at all times**, with an accuracy limited to around 100 metres for civilian use.**

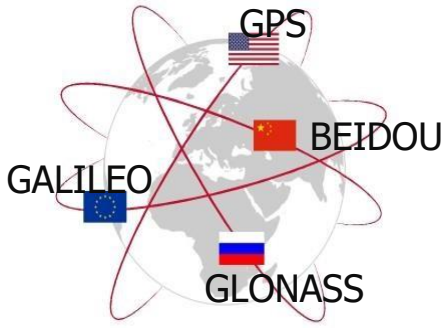
In 2000, President Bill Clinton confirmed the value of the technology for civilian purposes and authorised unrestricted broadcasting of GPS signals **with an accuracy of approximately ten metres. It was made available to the general public in mid-2000.**

The United States continues to develop its system by replacing and adding satellites and by making available additional GPS signals that are more accurate and require less power from

the receiving equipment. An interoperability agreement has also been confirmed between the GPS systems and Galileo, the system set up by the European Union, to ensure that the two systems use the same frequencies and are compatible with each other.

Note: GPS is a system, not a device. GPS is an American system. However, other positioning systems exist, including the following:

- Galileo from Europe (launched in 1999 by the European Union, operational;
- GLONASS from Russia. Launched from 1980, operational;
- Beidou from China. Launched in 2000, operational.



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Satellite systems (GPS & GLONASS) can be supplemented by so-called **overlay** systems, which deliver real-time corrections to increase accuracy, as well as information to guarantee the integrity of these corrections.

2.3. Understanding the GPS system and how it works

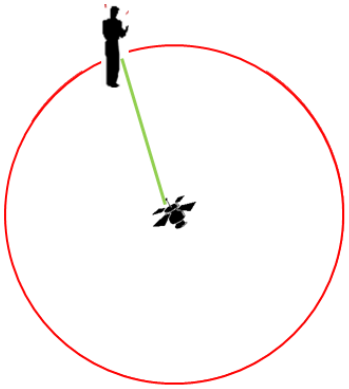
Signals transmitted by the satellites can be freely received and used by anyone. Users, whether on land, at sea or in the air, can find out their position at any time and in any place on or near the Earth's surface with unprecedented accuracy, as long as they are equipped with a GPS receiver and the software needed to process the information received (nowadays this applies to most mobile phones).

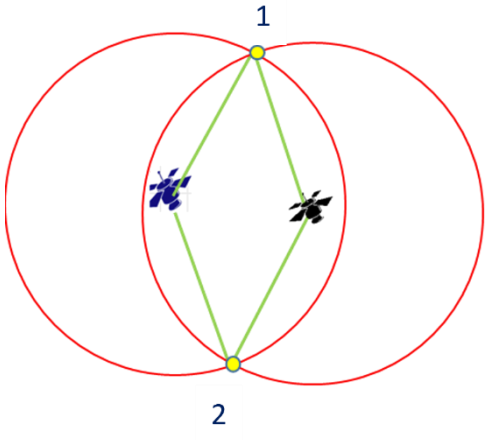
2.3.1. GPS operating principle

GPS positioning works with a method that you might already be familiar with: trilateration.

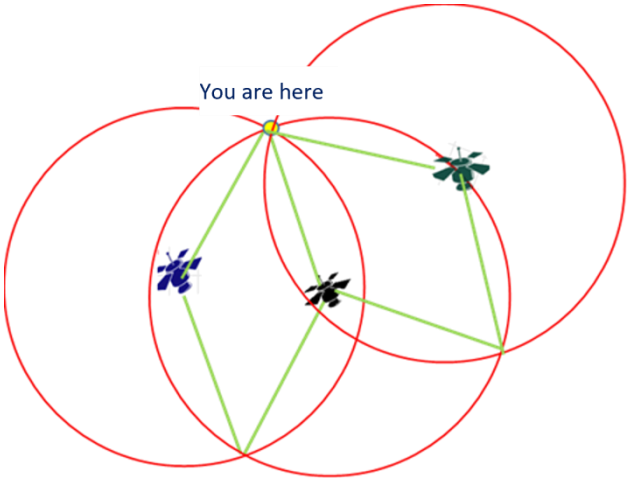
For a simplified explanation, imagine that you are moving around anywhere on Earth with a GPS receiver in your hand. The circle in red represents your distance to a GPS satellite orbiting earth above you.

Step 1: For the moment, with a single satellite, your GPS device cannot identify your position. It can only calculate the distance between your receiver (you) and the satellite. You may be anywhere on the red circle.





Step 2: Now your receiver will pick up another signal from a second satellite. At this moment, your receiver is doing calculations in the background to determine two positions, which is where the depicted circles intersect. You may be located at either of the two spots. Your exact position is still uncertain.



Step 3: Your receiver picks up the signal from a third satellite. Your distance from all three satellites, as depicted by the three circles, intersects at a single point. This is your position.

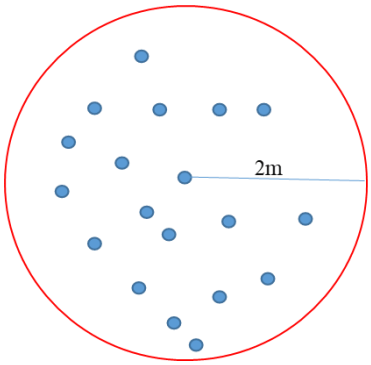
Note: In principle, 3 satellites suffice to determine your position (latitude, longitude and elevation), however, a 4th satellite is needed to synchronise the receiver's internal clock so that your position is more refined and precise.

2.3.2. Accuracy

Geographical accuracy is a concept that is closely linked to the positioning that a set of satellites can provide and is different from the concept of scale. Accuracy is the absolute difference between the values of the coordinates in a geographic dataset and the true values. In simple

terms, it is the difference between the position of the entity in the dataset provided by the positioning device and the true/actual position.

For example, if we say that the accuracy is 2 metres, then this literally means that the true position can be found at any point in a circle with a radius of two metres from the GPS-determined position.



2.4. What to remember?

GPS is not an electronic device but a positioning system from the USA. However, positioning devices operating on GPS and other systems are often simply referred to as 'GPS'.

GPS is not the only geolocation system, there are also Galileo from the EU, GLONASS from Russia, and Beidou from China.

GPS requires at least 4 satellites to give an accurate position.

Accuracy is a key factor in locating with any positioning system.

III- MODULE 3: COORDINATE REFERENCE SYSTEMS (CRS)

3.1. Purpose of the module

This module will briefly introduce the concept of Coordinate Reference Systems in cartography and geography.

3.2. What is a CRS?

CRS: A Coordinate Reference System (composed of a projection and a datum) is a reference frame in which elements in space can be represented. This system makes it possible to locate oneself on the entire globe using a pair of geographic coordinates.

The subject of **map projection** is very complex and even professionals who have studied geography, geodesy and other GIS-related sciences often have problems with the correct definition of map projections and reference coordinate systems. Usually, when you work with GIS, you have already projected the data to begin with. In most cases, this data will be projected into a certain CRS (most commonly the World Geodetic System 1984 or **WGS 84**, also known by its **EPSG code 4326**), so you don't need to create a new CRS or even project the data from one CRS to another. That said, it's always useful to have an idea of what 'map projection' and 'CRS' mean. For further information, please read Coordinate Reference Systems — QGIS Documentation.

3.3. The WGS 84 reference system

WGS 84 (World Geodetic System 1984) is a worldwide geodetic system. It comprises a coordinate system, a reference ellipsoid (the IAG GRS 80 resolution ellipsoid) and a geoid (EGM96). WGS 84 is used by the GPS satellite positioning system. WGS 84, also known by its **EPSG code 4326**, is usually set as the default CRS in many GPS devices. You should however make sure that that is the case before you start mapping.

IV- MODULE 4: GETTING STARTED WITH GPS

4.1. Purpose of the module

GPS is an important tool to know when you're involved in agriculture, forestry, and land management. The aim of this modul is to get to know a GPS receiver in a useful way, from its various functions to its handling.

4.2. Introducing GPS receivers

4.2.1. GPS functions

A GPS receiver can be used for a number of purposes, including:

- Calculating a location (main use);
- Calculating speed;
- Calculating the distance to a point or area;
- Calculating a route.

It can also be used as a compass and has memory space to save information.

4.2.2. Types of GPS receivers

There are several types of GPS receivers, as several manufacturers produce this type of electronic device. Some of the most commonly used are the following:

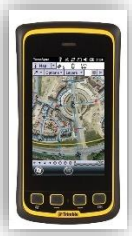
GARMIN




MAGELLAN



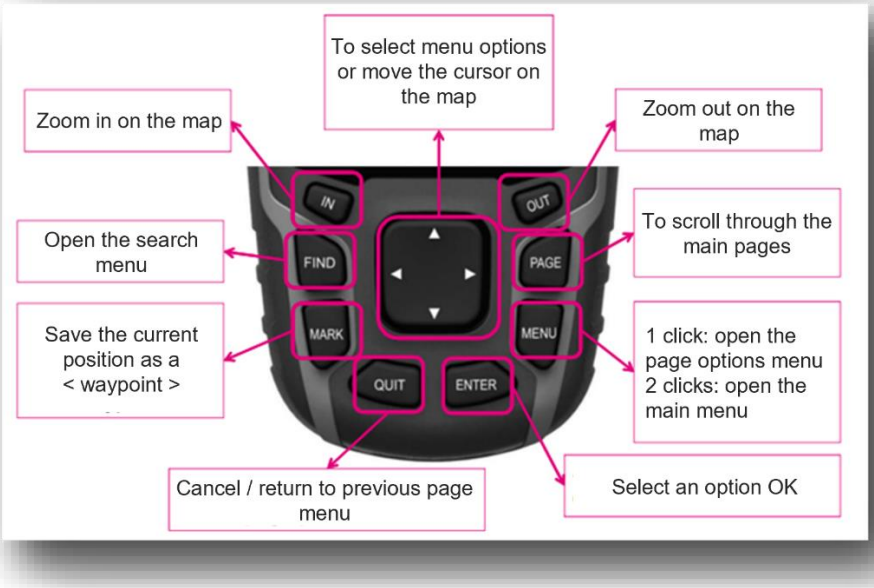

Trimble


4.2.3. Overview of the Garmin receiver

①	GPS/GNSS antenna
②	Buttons
③	On/off button
④	Mini-usb port (under the waterproof cap)
⑤	MCX connector for GPS antenna
⑥	microSD card reader (under the battery)
⑦	Battery compartment
⑧	Fixing groove
⑨	D-ring battery cover

4.2.4. Functions of the buttons



4.3. Display

The GPS receiver has several main pages that can be accessed using the button 

.
When you click the "**page**" button, you can choose to display one of the following pages:

Main Menu	Map	Compass
		
This page contains the main menu with a number of functions, including - Device setup - Waypoint management - Route planning - Zone calculation - Satellite overview - etc…	The **map** display page contains a **cursor** which indicates your current position on the map (when you move, the cursor moves, too).	When navigating, the compass indicates directions to follow and the direction of the destination (North, South, East, West).

Trip computer	Elevation plot
	
This page displays trip characteristics (current speed, average speed, distance travelled, etc...).	This page graphically displays altitude as a function of distance travelled.

4.4. Main menu functions

The main menu functions described below are essential for everyday use of the GPS receiver.

4.4.1. Setup menu

1. **Setting up the satellite positioning system(s) to be used:**
   GPS or GPS+GLONASS or GPS+GALILEO
2. **Setting the battery type**
   Alkaline/Lithium/Rechargeable NiMH
3. **Position format (type of coordinates)**
   Decimal degrees / UTM zone / etc…

Exercise: **Set the position format to**

- Decimal degrees: hddd.ddddd°
- UTM: UTM UPS

4.4.2. Waypoint manager

1. Waypoints: recorded positions stored in the GPS device's memory
2. The waypoint manager is used to modify or delete waypoints
3. Creating a waypoint: MARK button
4. Navigate to a waypoint: FIND button > Waypoints > Selection > Go

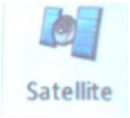
4.4.3. Track manager

A track is the automated recording of your route that combines the various points along the way recorded (time, location, altitude).
The Setup / Tracks menu is used to configure track recording:

1. Track log: enable or disable the recording of tracks
2. Recording method (distance, time, automatic)

Exercise: Delete the currently tracked route

4.4.4. Satellite



- The satellite page shows the satellites "seen" by the GPS receiver
- On start-up, the "satellite search" message is displayed.
- When a sufficient number of satellites (>4) are detected, the location can be calculated -> the Satellite page shows the current position, GPS accuracy, satellite location and signal strength

4.5. Practical exercises

Field exercise (groups of 2)

1. Recording of 10 waypoints + detailed description
   a. Starting point
   b. Various points of interest along a 100m route
2. View waypoints and tracks on the map

   Upon arrival:
3. View the characteristics of the route
4. View the altitude profile

Waypoint manager exercise:

1. Display the waypoints recorded in the waypoint list
2. Modify a waypoint (and add a comment)
3. Display the recorded waypoints on the map

V- MODULE 5: GETTING STARTED WITH THE GPS MOBILE APP

5.1. Purpose of the module

Besides professional GPS receivers, other devices such as most mobile phones can use the Global Positioning System with dedicated software. In this module, we will show you how to use the OSMTracker application for Android phones. With OSMTracker you can record precise coordinates, as well as take photos and notes when collecting data in the field.

5.2. Download the OSMTracker application and discover the interface

There are several mobile GPS applications for both Android an iOS. For the purposes of this course, we will use OSMTracker, because it is easy to access (free), easy to use and highly accurate (up to 2m).

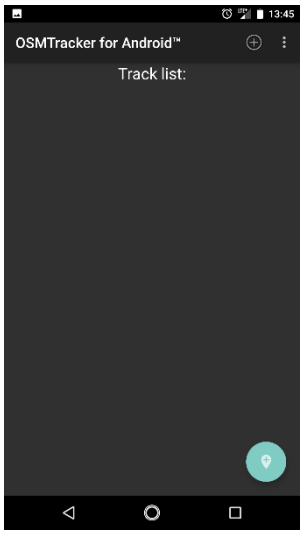
OSMTracker is an Android mobile application that lets you use your smartphone to collect geographical information and record your tracks, just like a professional GPS receiver.

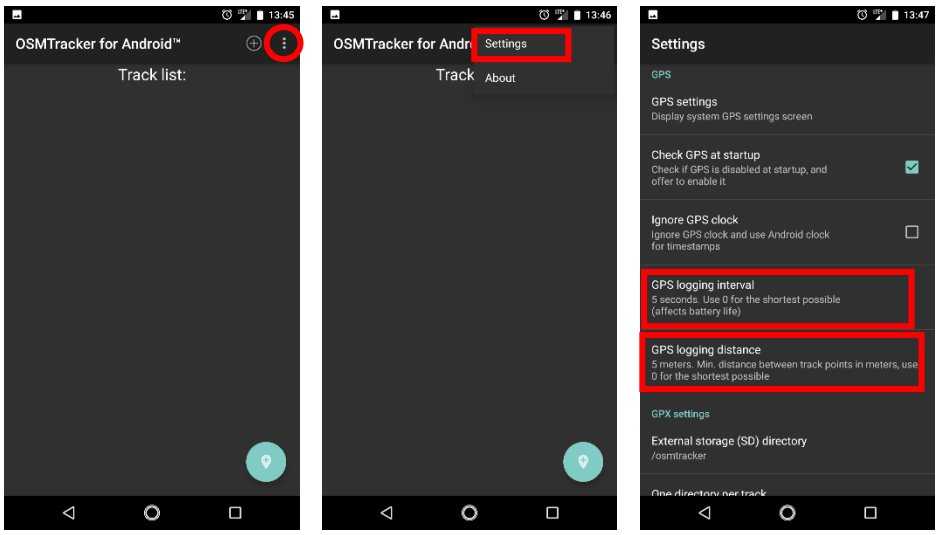
Download and install the OSMTracker application (available from the Google Play store).

5.3. Getting started with OSMTracker

On Android phones, you have to activate location services in your settings and make sure you are located outdoors to facilitate a fast reception of the GPS satellite signals.

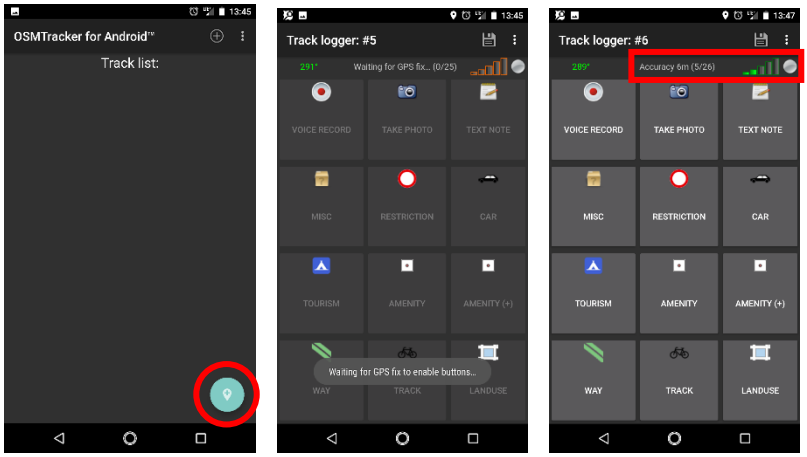
Once the application has started, the interface shown on the right will appear.





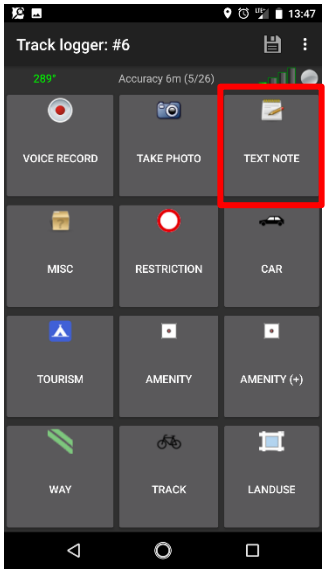
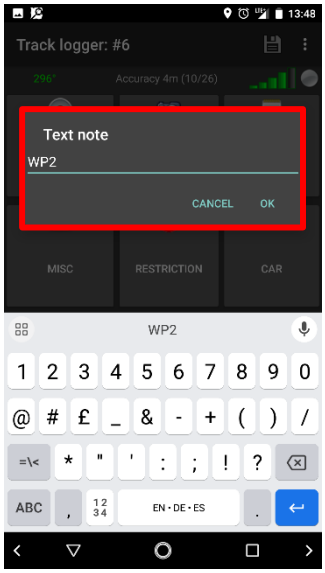
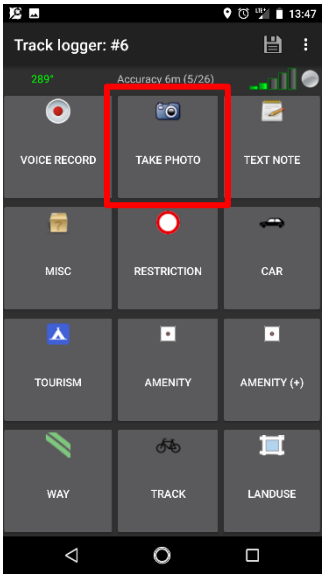
As soon as GPS signal reception is activated, the application starts to continuously record its location in the background. In order to obtain accurate data right from the start, we recommend that you configure the GPS settings first. To do this, click on the three dots at the top right and then on *"settings"*. In the *"GPS"* menu option, we now configure the tracking options so that your location is only recorded every 5 seconds (*"GPS logging interval"*) and from a minimum distance of 5 metres (*"GPS logging distance"*).

Now, back in the home view, we can click on the marker with the plus sign at the bottom right and start our GPS tracking.

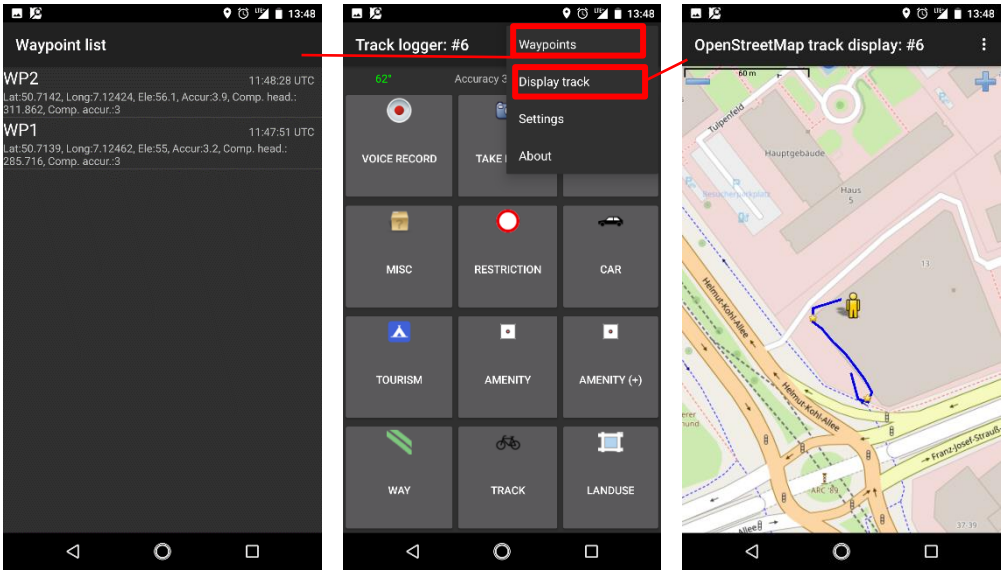


If satellite signals are not yet picked up, the data collection interface appears dark grey. As soon as enough signals are picked up, the interface becomes lighter, and the signal bars indicate that the satellite GPS signals are being received. After a short wait, the signal should improve, as shown in the example on the right.

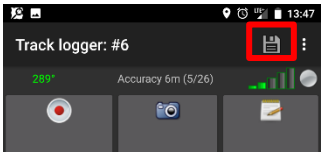
A GPS track is now automatically recorded in the background. You can start moving to record a track. If you want to mark **points of interest (POIs)** along the track (such as corners of a polygon), two main functions are used: the **TEXT NOTE** function and the **TAKE PHOTO** function.

TEXT NOTE: Used to pick up any type of POI at the current location, with a note to support it.		**TAKE PHOTO**: Allows geo-referenced photos to be taken.
Mark the point by clicking on the text note.	Make a note of the name of the point in the dialogue box that opens, and then accept.	Mark the spot by clicking on take picture. Then select the camera or a picture already taken from the gallery.
		

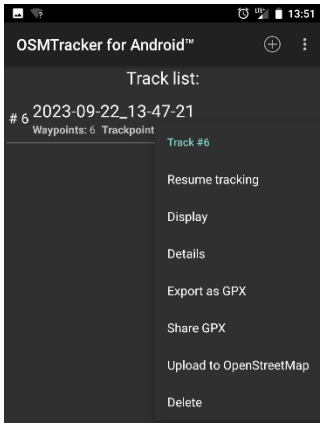
While in recording mode, you can use the three dots at the top right of the menu option to view both the **list of POIs recorded** ("Waypoints") so far and **the recorded track** ("Display track").



When you have **finished your recording**, you can save it at any time by clicking the 'save' icon at the top right.



After saving the track and its POIs, you can long-click its list entry for **different options**. Among other, you can resume the recording, view the details, visualize the track, export or share it as a GPX file and even upload it to OpenStreetMap (a collaborative geodata project). To find or change the storage location of your exported GPX file, open the *"settings"* menu (via the three dots at the top right), and scroll to *"GPX-Settings"*. Under the subitem *"External storage (SD) directory"* you can see and change the internal or external storage location of your GPX directory.



Feel free to try visualizing the track and exporting it as a GPX file.

Note:

Weak points: The OSMTracker application can only be used on Android devices, it does not work on iPhones.

Strengths: Flexible, free, up to 2m accuracy, powerful satellite connection capability (fast connection, even in difficult environments as you don't need an internet connection).

VI- MODULE 6: DISCOVERING QGIS

6.1. Purpose of the module

This module is dedicated to describing the QGIS software. It is a cartographic software package for processing and analysing data. It is used to view, process, and analyse the data collected with GPS in the field. This section will show you how to download and install QGIS. You will also learn about its interface and become familiar with it.

6.2. History of QGIS

QGIS is a free, multi-platform GIS (Geographic Information System) software released under General Public License (GPL). The project began in May 2002. It was also called Quantum GIS until September 2013.

QGIS is a Free and Open Source Software.

- OPEN-SOURCE SOFTWARE

As the name suggests (open), the idea behind this concept is openness. Open-source software is open in the sense that anyone can access its source code and create derivative software products. The Open Source Initiative (an organization founded in 1998 by Bruce Perens and Eric Raymond) focuses on technical and not commercial considerations. It is compatible with software whose code is open but not free. In practice, however, a significant proportion of open-source software is indeed free to use.

- FREE SOFTWARE

The free software movement goes further and advocates philosophical values. Some would say it is almost political.

Described for the first time in the 1980s by Richard Stallman, and popularised by his very strong campaigns (with very strong opinions) via the Free Software Foundation (FSF), the formal definition of free software is based on four freedoms:

1. Freedom to run the program for any purpose.
2. Freedom to study how the program works and adapt it to your needs.
3. Freedom to redistribute copies. Underlying principle or philosophy: to help others.
4. Freedom to improve the program and publish improvements. Underlying philosophy: to benefit the whole community.

Two of these freedoms (the freedom to study how a program works and the freedom to improve it) imply de-facto access to the source code and therefore that the software is open-source.

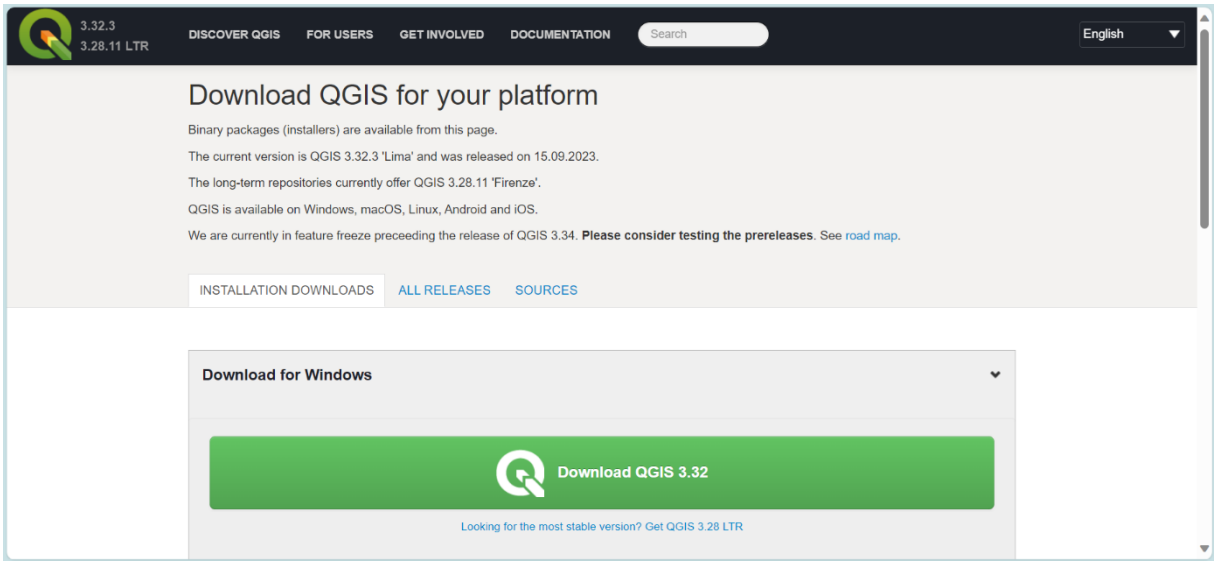
NB: Open-source software is not necessarily free.

6.3. Downloading and installing QGIS

❖ Download QGIS

The procedure for obtaining QGIS is very simple. Just go to their official download site: https://www.qgis.org/en/site/forusers/download.html.

From this site, you will find the latest versions of the software, the various updates and the stable versions of the software. The figure below shows the site interface.



To download the software, simply click on "Download QGIS" and follow the procedure.

It is advisable to use the latest stable version (Long Term Release – LTR) of the software, compatible with your environment (operating system, hardware architecture). QGIS LTR versions are more robust, with a better bug management.

The QGIS site policy highlights the latest version. To download the stable LTR version, use the link right below the big green button:

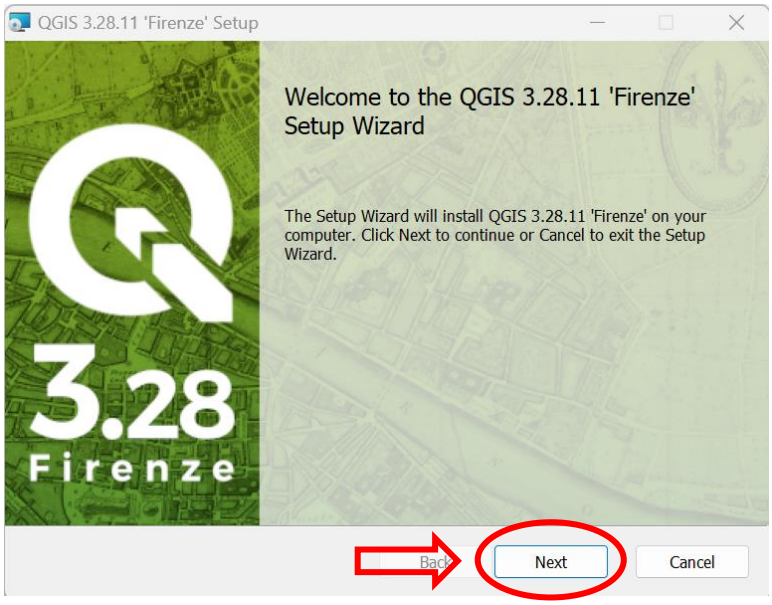
❖ Version semantics

	Major version	Minor version	Correction
Numbering	X.	Y.	Z
Example 1	2.	18.	28
Example 2	3.	22.	11
Characteristics	Non backward-compatible changes. Major evolutions bring new functionalities, radically changing the appearance or architecture of the software.	Additions of backward-compatible functionalities, mainly bug fixes, and additions of some functionalities.	Corrections of backward-compatible anomalies, or security flaws

At the time of writing, (stable) version 3.28 includes more than 4 patches. This continuous updating of the software is why we recommend working with stable versions, even if you won't be up to date with all the latest QGIS developments.

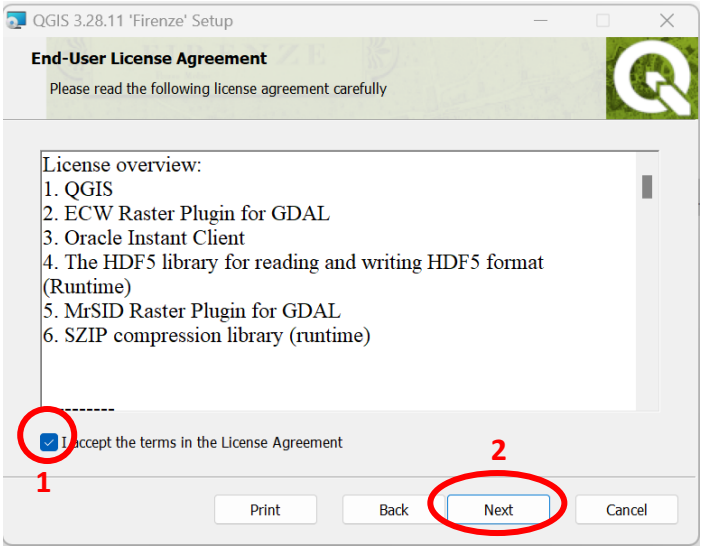
❖ Installing QGIS

After downloading, double-click on the downloaded file, which is probably located in your download folder. An installation window will appear giving you instructions to follow. As soon as the following window appears, click “Next”.

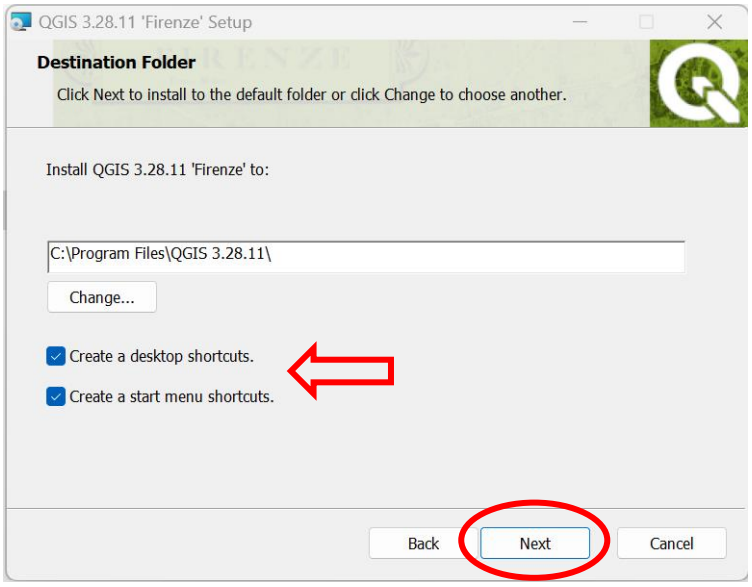


Then,

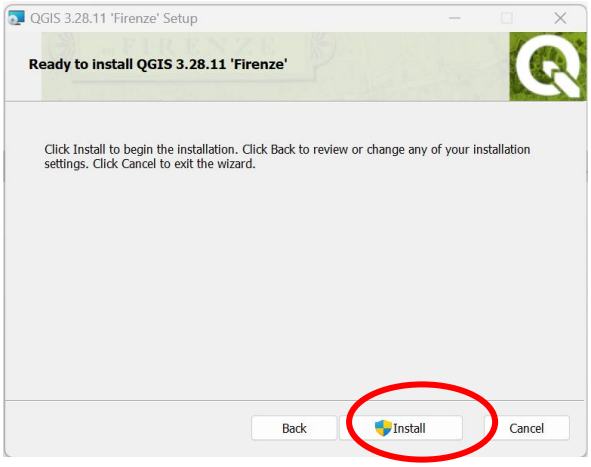
1- Tick the box: "I accept the terms in the License Agreement"
2- Click "Next"

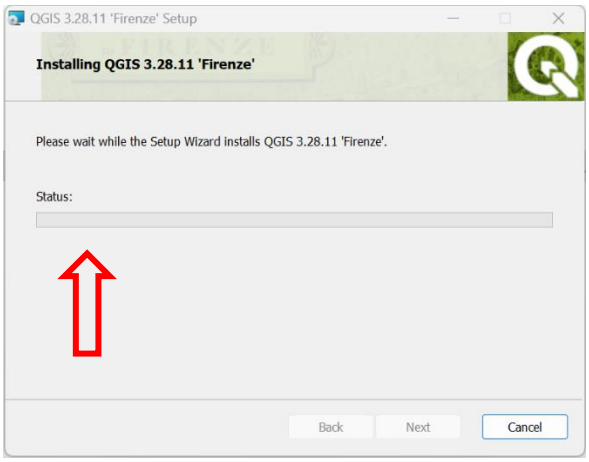


If you want to have shortcuts on your desktop and in the taskbar, tick both boxes as shown in the image below, then click 'Next'.

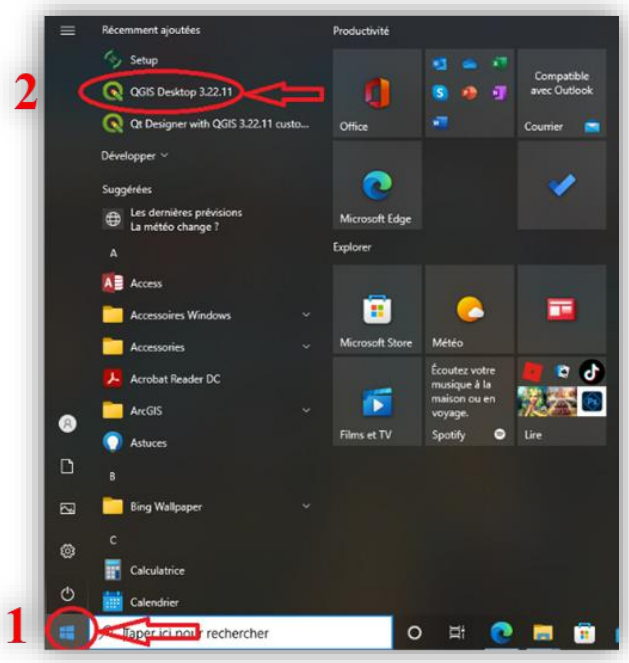


Start the installation process by clicking 'Install' (you might have to enter your Windows user password); this process will take a few minutes.





Once the installation is complete, click 'Finish'. Check whether the software is now available on your computer and open it.

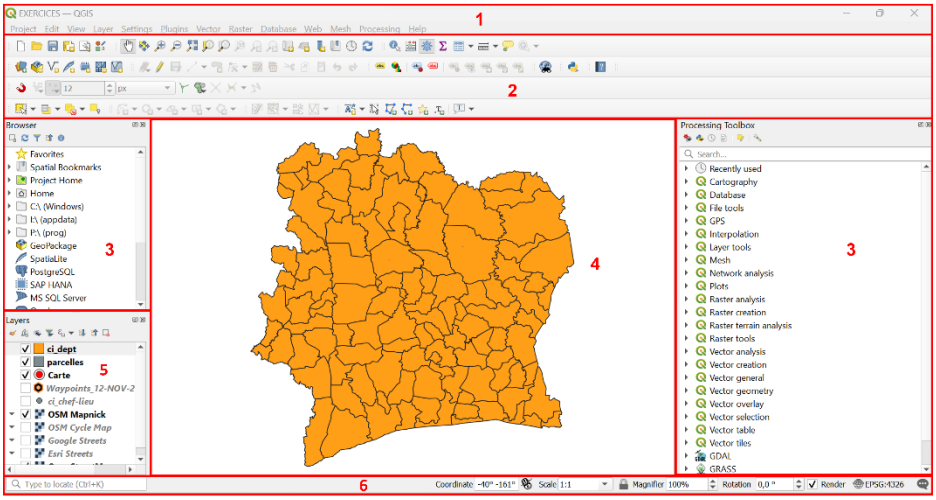


6.4. Discovering QGIS: Getting started

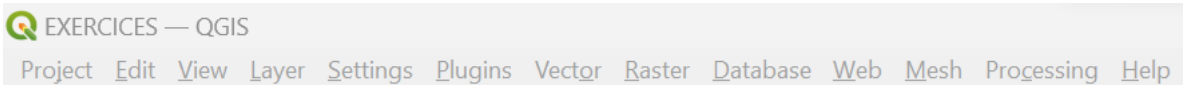
❖ Understanding the QGIS interface

Note: The official QGIS documentation is available here.

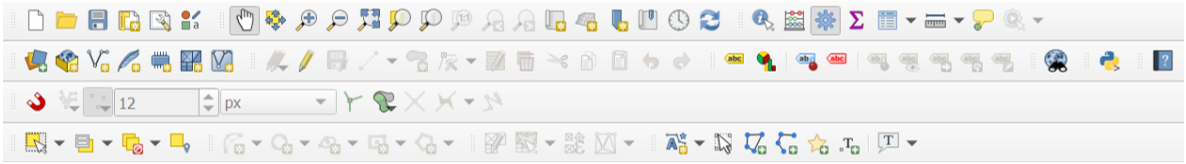
Once QGIS is open, you'll see its interface, which we'll explore together.



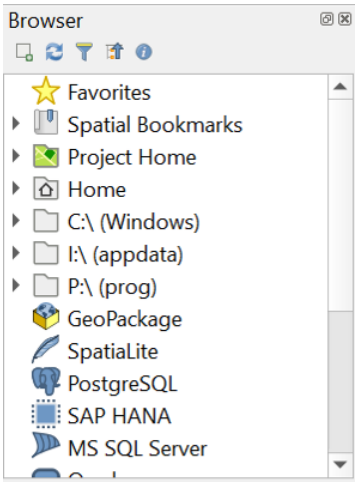
Menu bar (1)

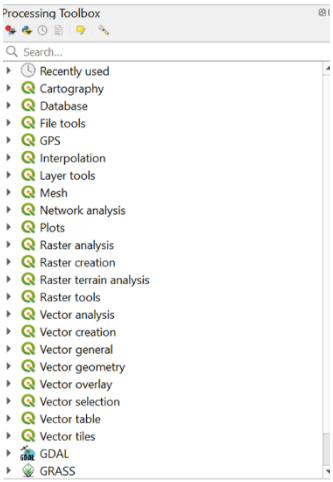


Toolbars *(modifiable view)* (2)



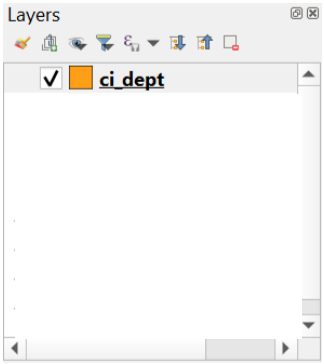
Navigation panels *(modifiable views and selections)* (3)





Map view (4)

Layer panel (5)



Status bar (6)

6.5. Main menu bar in QGIS

The menu bar provides access to QGIS functions.

Below is a description of the standard hierarchical menus. Note that extensions can add new options to the menus.

The Project menu

The **"Project"** menu provides access and output points for the project file. It provides tools for:

- Create a **"New"** project file from scratch or use another project file as a template
- **"Open"** a project from a file, a GeoPackage or a PostgreSQL database
- **"Close"** a project or return it to its last saved state
- **"Save"** a project in .qgs or .qgz format, in a file, a GeoPackage or a PostgreSQL database
- **"Export"** the map canvas in different formats or use the layout sub-section for more complex outputs.
- Set project **"Properties"** and **"Snapping Options"** for geometry editing.

The Edit menu

The **Edit** menu provides most of the native tools needed to edit layer attributes or geometry (see Editing for details).

"Edit" menu items
Undo
Redo
Cut features
Copy features
Paste features

Paste features as ▶

▶ New vector layer...

▶ Temporary scratch layer...

Delete selected

Select ▶

▶ Select Feature(s)

▶ Select Features by Polygon

▶ Select Features by Freehand

▶ Select Features by Radius

▶ Select Features by Value...

▶ Select Features by Expression...

▶ Deselect Features from All Layers

▶ Deselect Features from the Current Active Layer

▶ Reselect Features

▶ Select All Features

▶ Invert Feature Selection

Add a record

Add Point Feature

Add Line Feature

Add Polygon Feature

Add a curve

Add a circular string by radius

Add a circle ▶

▶ Circle from 2 points

▶ Circle from 3 points

▶ Circle from 3 tangents

▶ Circle from 2 tangents and a point

▶ Circle by a center point and another point

Add a rectangle ▶

- ▶ Rectangle from extent
- ▶ Rectangle from center and a point
- ▶ Rectangle from 3 points (distance from the 2nd to 3rd point)
- ▶ Rectangle from 3 points (distance from the point projected onto segments p1 and p2)

Add a regular polygon ▶

- ▶ Regular Polygon from center and a point
- ▶ Regular Polygon from center and a corner
- ▶ Regular Polygon from 2 points

Add an ellipse ▶

- ▶ Ellipse from center and 2 points
- ▶ Ellipse form center and a point
- ▶ Ellipse from Extent
- ▶ Ellipse from Foci

Add annotation ▶

- ▶ Text Annotation
- ▶ Form Annotation
- ▶ HTML Annotation
- ▶ SVG Annotation

Edit Attributes ▶

- ▶ Modifying Attributes of Selected Entities
- ▶ Merge Attributes of Selected Entities

Edit Geometry ▶

- ▶ Move Feature(s)
- ▶ Copy and Move Feature(s)
- ▶ Rotate Feature(s)
- ▶ Scale Feature(s)
- ▶ Simplify Feature(s)
- ▶ Add Ring

▶ Add Part
▶ Fill Ring
▶ Delete Ring
▶ Delete Part
▶ Reshape Feature(s)
▶ Offset Curve
▶ Split Feature(s)
▶ Split Parts
▶ Merge Selected Features
▶ Vertex Tool (All Layers)
▶ Vertex Tool (Current Layer)
▶ Reverse line
▶ Trim/Extend Feature
Rotate Point Symbols
Offset Point Symbol

Tools that can be used based on the type of geometry of the selected layer, i.e., point, polyline, or polygon:

Menu bar	Point	Polyline	Polygon
Move Feature(s)			
Copy and Move Feature(s)			

The View menu

The map is displayed in the map view (large main screen). You can interact with these views using the tools in the View menu. For example, you can:

- Create new 2D or 3D map views in addition to the main map canvas;
- Zoom in and out or move around the map;
- Query the attributes or geometry of displayed entities;
- Enhance the map display with preview modes, annotations, or decorations;
- Activate/deactivate any panel or toolbar.

The menu also allows you to reorganise the QGIS interface:

- **Toggle Full Screen Mode**: covers the entire screen while hiding the title bar and the Windows task bar;

- **Toggle Panel Visibility**: displays or hides activated panels - useful when digitising features (for maximum visibility of the canvas) and for presentations (projected/recorded) using the main QGIS canvas;
- **Toggle Map Only**: hides the panels, toolbars, menus and status bar and displays only the map canvas. Combined with the full screen option, it allows your screen to display only the map. (It is advisable to remember the keyboard shortcut CTRL+Shift+Tab to go back to the default view.)

"View" menu items
New Map View
3D Map Views ▶
▶ New 3D Map View
▶ Manage 3D Map Views
Pan Map
Pan Map to Selection
Zoom In
Zoom Out
Identify Features
Measure ▶
▶ Measure Line
▶ Measure Area
▶ Measure Bearing
▶ Measure Angle
Statistical Summary
Elevation Profile
Zoom Full
Zoom to Selection

 Zoom to Layer(s)

 Zoom to Native Resolution (100%)

 Zoom Last

 Zoom Next

Decorations ▶

- ▶  Grid...
- ▶  Scale Bar ...
- ▶  Image...
- ▶  North Arrow...
- ▶  Title Label...
- ▶  Copyright Label...
- ▶  Layout Extents...

Preview Mode ▶

- ▶ Normal
- ▶ Simulate Monochrome
- ▶ Simulate Achromatopsia Color Blindness (Grayscale)
- ▶ Simulate Protanopia Color Blindness (No Red)
- ▶ Simulate Deuteranopia Color Blindness (No Green)
- ▶ Simulate Tritanopia Color Blindness (No Blue)

 Show Map Tips

 New Spatial Bookmark...

 Show Spatial Bookmarks

 Show Spatial Bookmark Manager

 Refresh

Layer Visibility ▶

- ▶  Show All Layers
- ▶  Hide All Layers
- ▶  Show Selected Layers

▶ Hide Selected Layers
▶ Toggle Selected Layers
▶ Toggle Selected Layers Independently
▶ Hide Deselected Layers
Panels ▶ activate and deactivate any panel
Toolbars ▶ activate and deactivate any toolbar
Toggle Full Screen Mode
Toggle Pane Visibility
Toggle Map Only

Note: Under Linux KDE, the **Panels ▶**, **Toolbars ▶** and **Switch to full screen mode menus** are in the **Preferences** menu.

The Layer menu

The **Layer** menu provides a wide range of tools for **creating** new data sources, **adding them** to the project or **saving** changes to them. Using the same data sources, you can also:

- **Duplicate** a layer to generate a copy where you can modify the name, style (symbology, labels, etc.), joins, etc. The copy uses the same data source as the original;
- **Copy** and **Paste** layers or groups from one project to another as a new instance whose properties can be modified independently. As with *Duplicate*, layers are always based on the same data source;
- **Embed layers and groups** from another project, e.g., from a read-only copy that you can't modify.

The **Layer** menu also contains tools for configuring, copying, and pasting layer properties (style, scale, Coordinate Reference System, etc...).

"Layer" menu items
Data Source Manager
Create Layer ▶
▶ New GeoPackage Layer...
▶ New Shapefile Layer...
▶ New SpatiaLite Layer...
▶ New temporary Scratch Layer...

- New Mesh Layer...
- New GPX Layer...
- New Virtual Layer...

Add Layer ▶

- Add Vector Layer...
- Add Raster Layer...
- Add Mesh Layer...
- Add Delimeted Text Layer...
- Add PostGIS Layer...
- Add SpatialLite Layer...
- Add MS SQL Server Layer...
- Add Oracle Spatial Layer...
- Add SAP HANA Spatial Layer...
- Add/Edit Virtual Layer...
- Add WMS/WMTS Layer...
- Add XYZ Layer...
- Add ArcGIS REST Service Layer...
- Add WCS Layer...
- Add WFS Layer...
- Add Vector Tile Layer...
- Add Point Cloud Layer...
- Add GPX Layer...

Embed Layers and Groups

Add from Layer Definition File...

Georeferencer

Copy Style

Paste Style

Copy Layer

Paster Layer/Group

 Open Attribute Table

Filter Attribute Table ▶

▶  Open Attribute Table (Selected Features)

▶  Open Attribute Table (Visible Features)

▶  Open Attribute Table (Edited and New Features)

 Toggle Editing

 Save Layer Edits

 Current Edits ▶

▶ Save for Selected Layer(s)

▶ Rollback for Selected Layer(s)

▶ Cancel for Selected Layer(s)

▶ Save for all Layers

▶ Rollback for all Layers

▶ Cancel for all Layers

Save as...

Save As Layer Definition File...

 Remove Layer/Group

 Duplicate Layer(s)

Set Scale Visibility of Layer(s)

Set CRS of Layer(s)

Set Project CRS from Layer

Layer Properties...

Filter...

 Labelling

 Show in Overview

 Show All in Overview

 Hide All in Overview

The Settings menu

“Settings“ menu items
User Profiles ▶
▶ default
▶ Open Active Profile Folder
▶ New Profile...
 Style Manager...
 Custom Projections...
 Keyboard Shortcuts...
 Interface Customization...
 Options...

The Plugins menu

QGIS is based on a system of extensions. This makes it easy to add new features to the software. Some QGIS functions are implemented as extensions. QGIS extensions are either main extensions or external extensions.
Main extensions are maintained by the QGIS development team and are automatically part of every QGIS distribution.

To install an extension, go to the menu **Plugins** and select **Manage and Install Plugins...**

NB: The main extensions may not all be loaded when you start QGIS for the first time, which is why you need to know how to download and install extensions in QGIS.

The Vector menu

The vector menu is used to process and analyse all vector layers that can be modified in any way.
By default, QGIS adds Processing algorithms to the **Vector** menu, grouped by sub-menus. This provides shortcuts for many common vector-based GIS tasks from different providers. If not all these sub-menus are available, enable the "Processing" plugin in
Plugins ▶ Manage and Install Plugins...

The Raster menu

The raster menu is used to process and analyse all pixel layers (image, photo, etc.).

VII- MODULE 7: HANDLING GPS DATA WITH QGIS

7.1. Purpose of the module

This module shows you how to process data once you have collected them in the field.

This stage of the course is all about making the data "speak". Therefore, you will learn how to import GPX data into QGIS, create shapefiles, and transform point data to lines or polygons.

7.2. Processing GPS data in QGIS

In this section, you will learn how to transfer data to the computer for its use in the QGIS software.

7.2.1. Connecting the GPS receiver to the computer to retrieve GPX data

The most common procedure is to incorporate the data from a file in .gpx-format produced by the GPS receiver or OSMTracker.

GPX data generated by a "Garmin" receiver

1: Connect the GPS receiver to the computer via cable;

2: When the computer prompts that the device is connected, open the File Explorer/Finder, navigate to the device and open the folder **"Garmin"**;

3: Then open the folder **"GPX"**;

4: Copy the GPX file containing the date of collection in its name onto the computer's hard drive (in our case, three files are copied);

5: Paste the copied file into a folder previously created on the computer (in our case, we named the folder "*DATA_GPS_COLLECTER*".

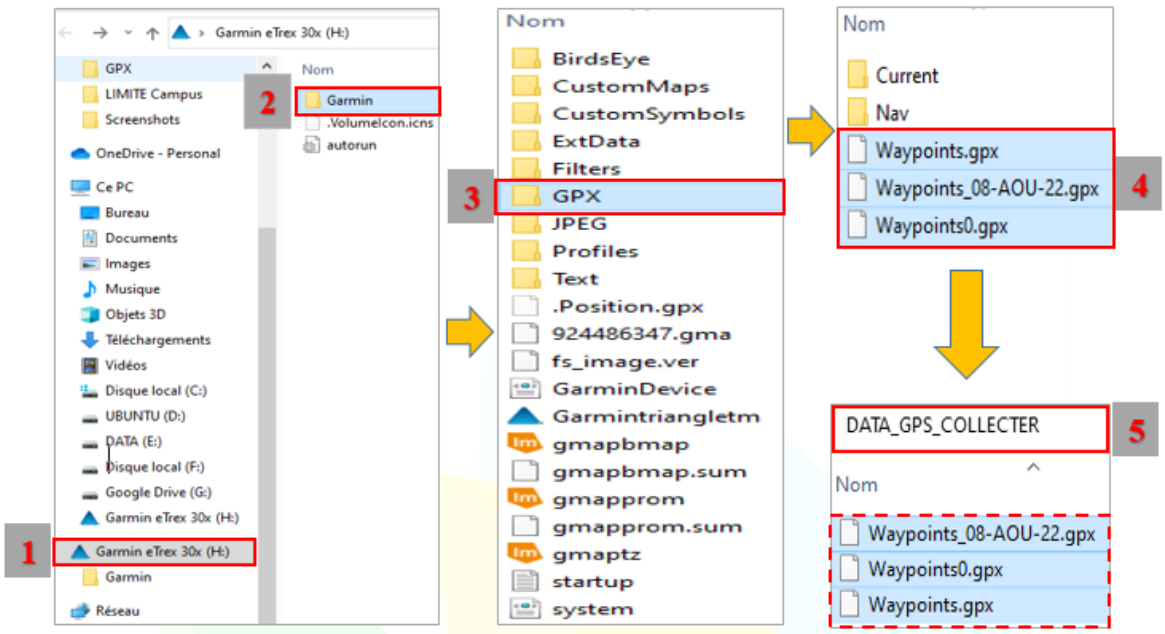


Figure: Steps for transferring GPX data from the GPS device to the computer

GPX data generated by OSMTracker

1. Export the GPX file from OSMTracker to your phone storage (named by the date);
2. Connect your phone with the computer and navigate to the storage directory;
3. Copy the GPX file and paste it into a folder previously generated on the computer, e.g. "*DATA_GPS_COLLECTER*".

7.2.2. Importing GPX data into QGIS

Launching QGIS after installation

There are three very simple ways to open the QGIS software.

The first is to type the word "QGIS Desktop" in the search bar, and the software logo is immediately displayed. All the user has to do is click on the logo.

The second option is to double-click the software logo on the desktop.

The third option is to open the "Start" menu, then search for the QGIS software. Once you've found it, click on the logo.

Importing data into QGIS

Several methods can be used to import the data extracted from the GPS receiver, which are now located in the folder *"DATA_GPS_COLLECTER"*, into the QGIS software.

1. The simplest method is the "**Select and Drag and Drop**" technique. In this technique, hold down the "Ctrl" button on the computer keyboard, click on all the files you would like to import into QGIS (one click each file only), then drag the data and drop them into the software's map view area.
2. The import technique from the QGIS Browser panel, depending on the type of data (Vector or Raster or others such as GPX): This technique involves first of all searching for and identifying the data to be imported using the QGIS "Browser" panel, which allows you to browse directories and explore data. Navigating to your GPX files you will find the following subitems: *"route_points"* (POINTS), *"routes"* (LINES), "track_*points"* (POINTS), *"tracks"* (LINES), *"waypoints"* (POINTS). In our example we only copied "***waypoints.gpx***" from the GPS receiver, correspondingly only *"waypoints"* will contain data. In case you are working with GPX files from OSMTracker, you have also exported

the track that you have walked with your mobile phone. Therefore, the subitems *"waypoints"*, *"tracks"*, and *"track_points"* will contain data.

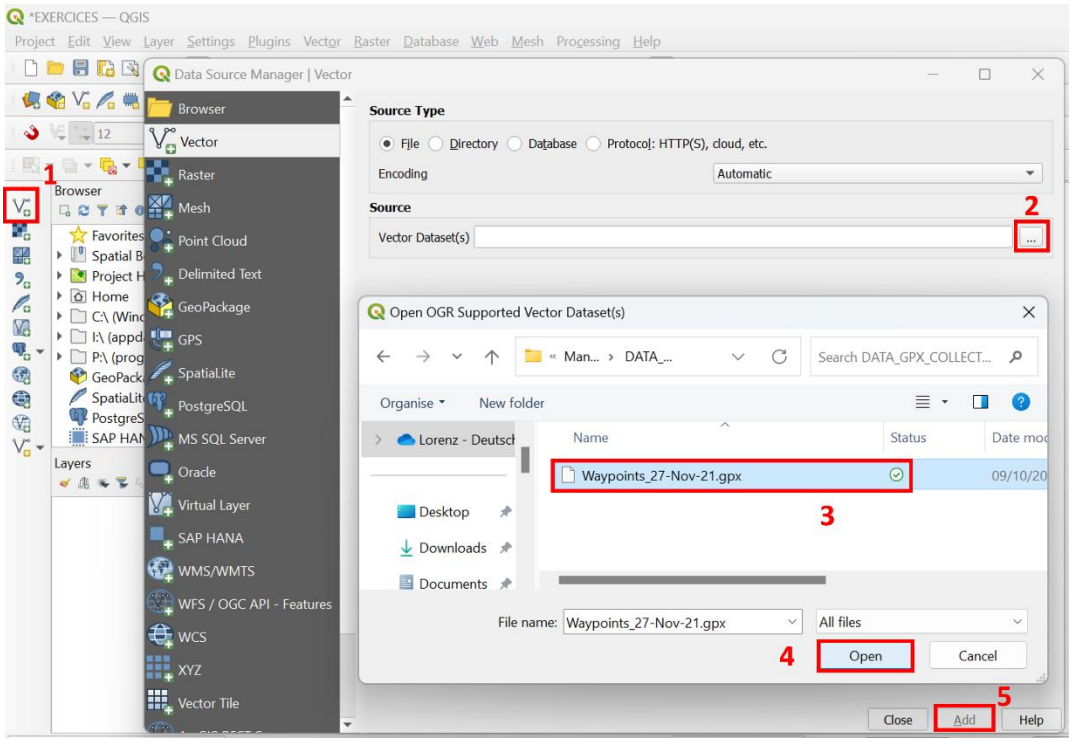
3. **Importing GPX data** from the "***Layer Manager***" toolbar

Importing **vector** data from the ***"Manage Layers Toolbar"*** next to the "browser" panel

Importing **raster** data from the ***"Manage Layers Toolbar"*** next to the "browser" panel

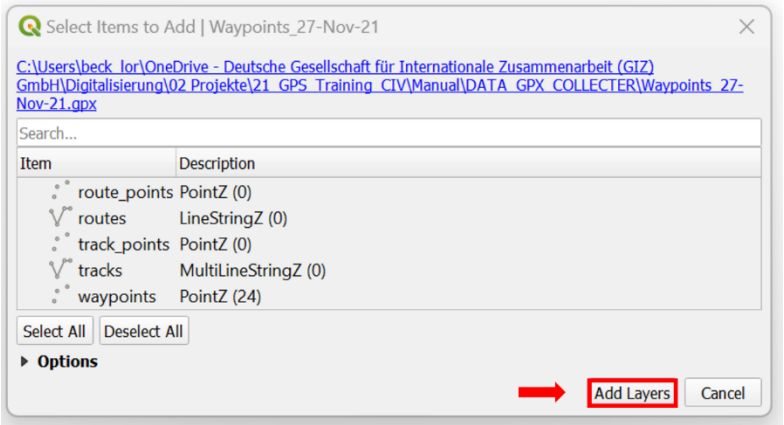
...

(If you don't see these buttons, activate them in the ribbon under "View" --> "Toolbars" --> "Manage Layers Toolbar".)

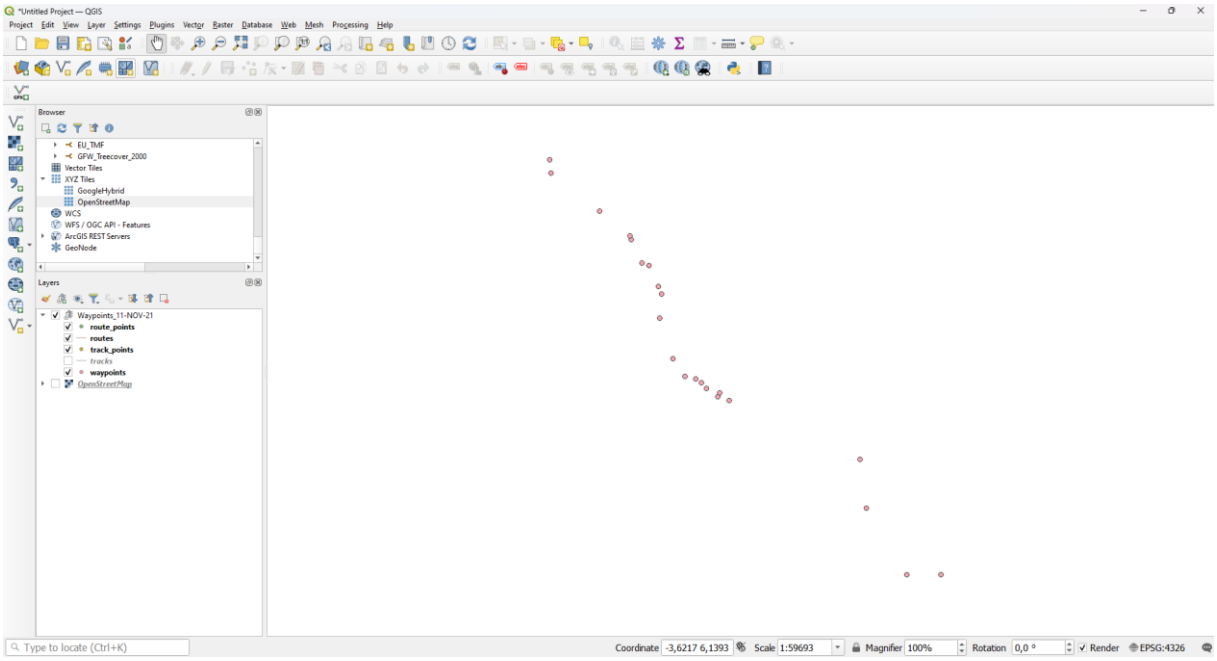


- Click on the "**Add a vector layer**" icon (1);
- Click on the browse icon marked with three dots [...] (2);
- Select the data you want to import (3), then click ***"Open"*** (4);
- Click ***"Add"*** (5).

Once you've clicked "**Add**", a dialogue box will open showing you the existing data within the GPX file. You can either select all layers or select specific data and click on ***"Add Layers".***



Example of the successful import of waypoints:



NB: The same processes apply to importing Raster data.

For a more detailed manual please refer to the QGIS documentation on working with GPS data.

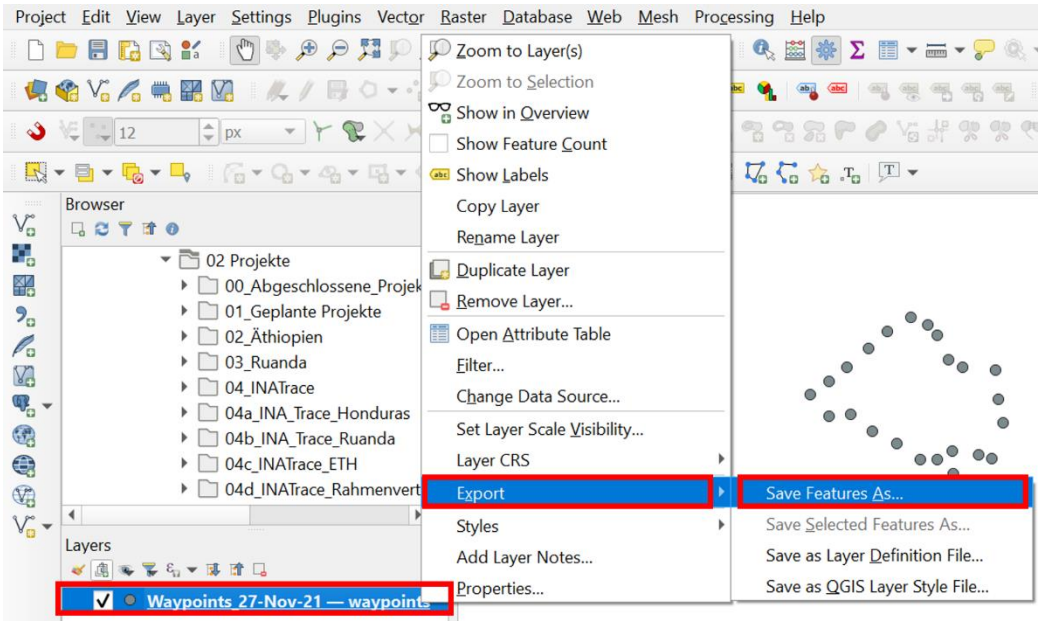
7.3 Creating a data base / export to shapefile

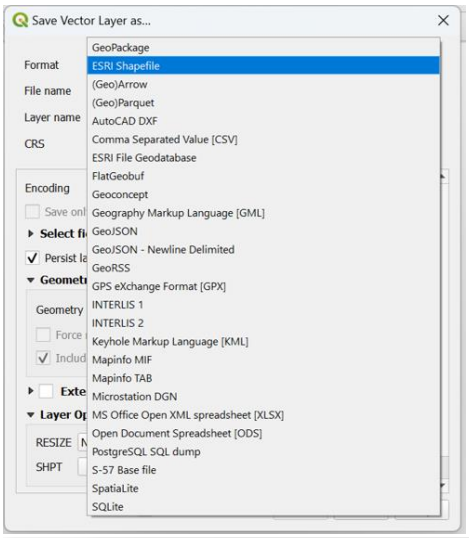
By definition, a database is a collection of information organized in such a way that it can be easily accessed, managed and updated. It is used by organizations as a method of storing, managing and retrieving information.

In this case, the database is a folder dedicated to structuring the generated data. In our case, the data will be located in the "*DATA_GPX_COLLECTER*" folder, which already contains our GPX files. This folder, containing all the data created (points, lines, polygons), represents the geographic database.

- Convert and export GPX data to shapefile

There are several steps to exporting data. Right-click the layers/data concerned, then click *"Export"*, then *"Save Features As…"*.

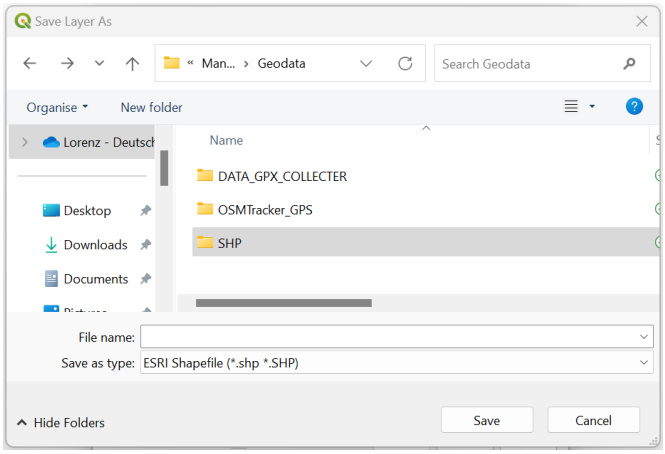


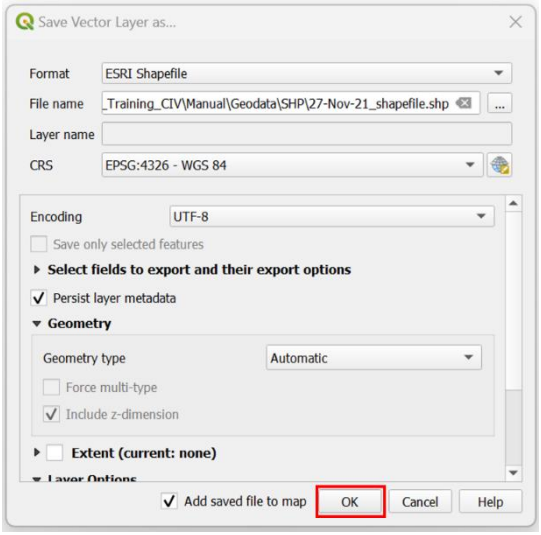


The dialogue box *"Save Vector Layer as.."* opens. Select **ESRI Shapefile** as the output format.

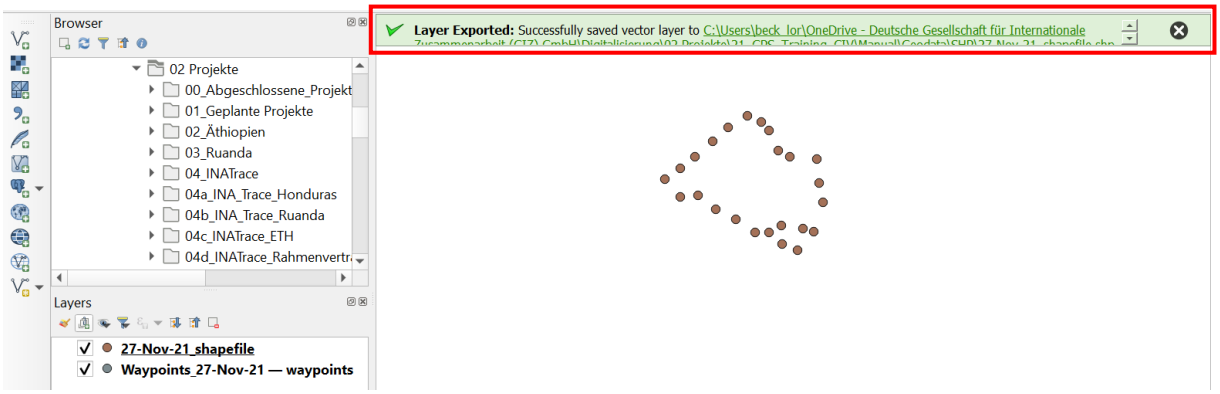
Open the browser dialogue by clicking on the button with three dots to the right of 'File name'. Navigate to your desired location (insert a new folder called *"SHP"* – short for shapefile), type in a name for the new shapefile layer and click *"Save"*.

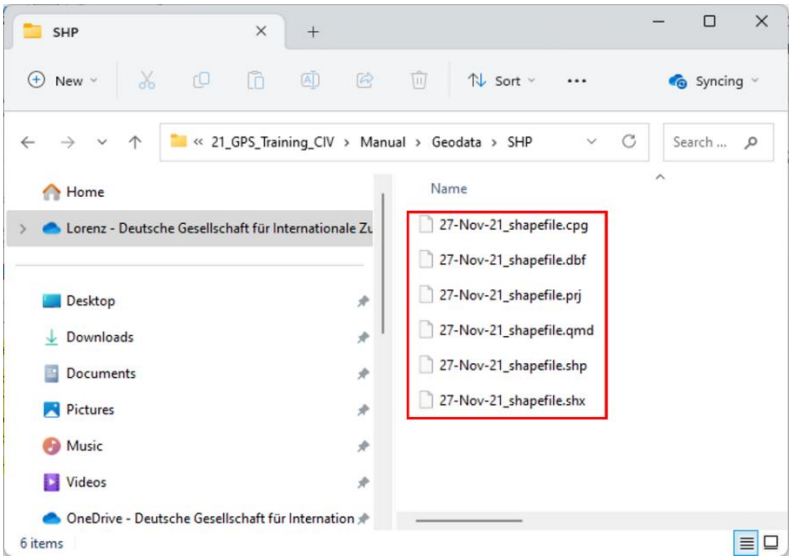
Click on *"OK"* to convert the GPX file into a shapefile.





If the conversion was successful a notification pops up at the top of the map view.





If you now browse to the file path, there will be several files in your ***"SHP"*** folder. All files together compose your exported shapefile. The single files are linked to each other and contain different information, such as the CRS within .prj, the attribute table in .dbf and the geometrical shape in .shp. Use the file ending on "***.shp***" if you want to import files (select or drag and drop) into QGIS again.

7.4 Understanding the data attribute table

The **"attribute data"** in a geographic data file, or **"attribute table"**, is easily accessible in QGIS. Each **column** in the attribute table, also known as a **"field"**, contains information (or a "variable") describing the spatial features (e.g., name, classification, area, etc...).
This data can be used for various operations, such as:

- **Data selection**: for example, to select countries whose demography is higher than a given value.
- **Using a symbology**: for example, to assign a colour to the data according to its importance.

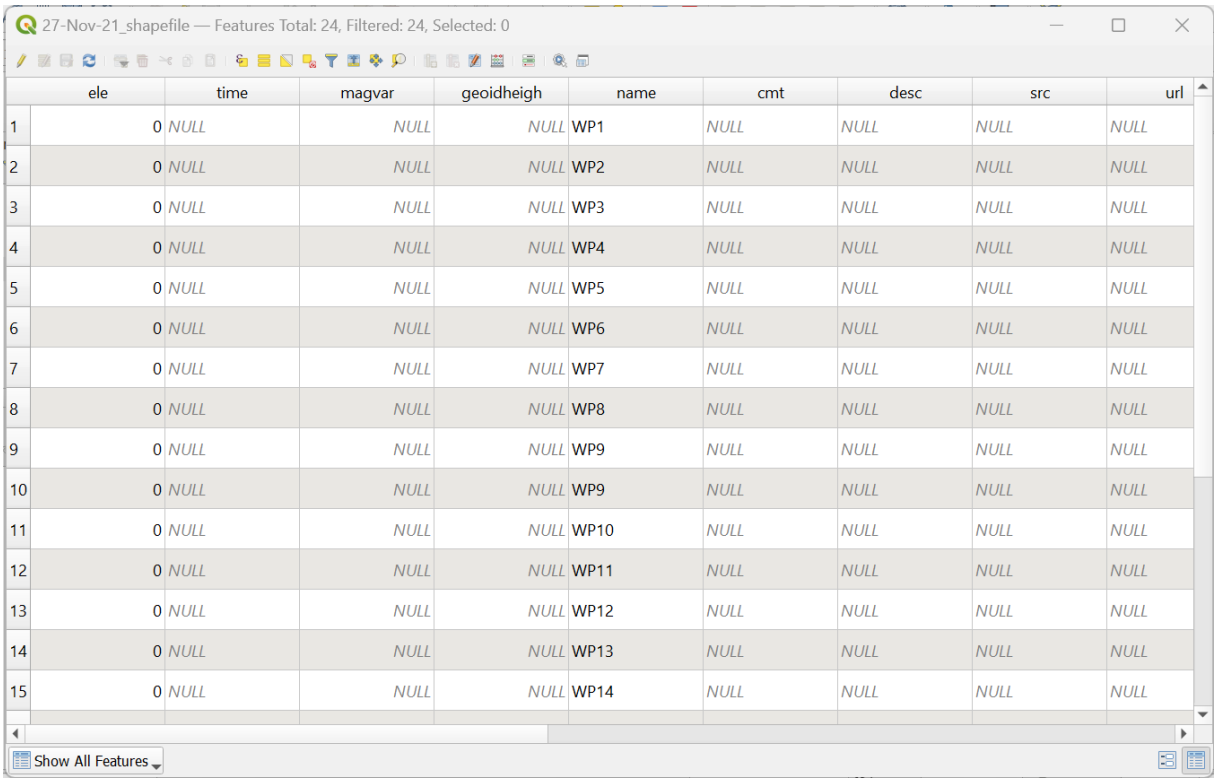
In the attributes table, a row (or a "record") corresponds to a spatial entity (or a "feature"). One spatial feature can be a single geometry (one point, one line, one polygon) or be made up of several spatially distinct polygons, lines or points. In the second case it is referred to as a "multipart feature".

7.5 Adding coordinate information into the attribute table of GPS points

Why generate the coordinates automatically when we sometimes have a notepad or an information sheet in which we noted the coordinates by hand during a field campaign?

Because data are very sensitive element and should not be manipulated unless absolutely necessary. Once they are wrongly noted, the information extracted from the raw data will become distorted. Each coordinate is unique and just like DNA, there are no 2 similar coordinates.

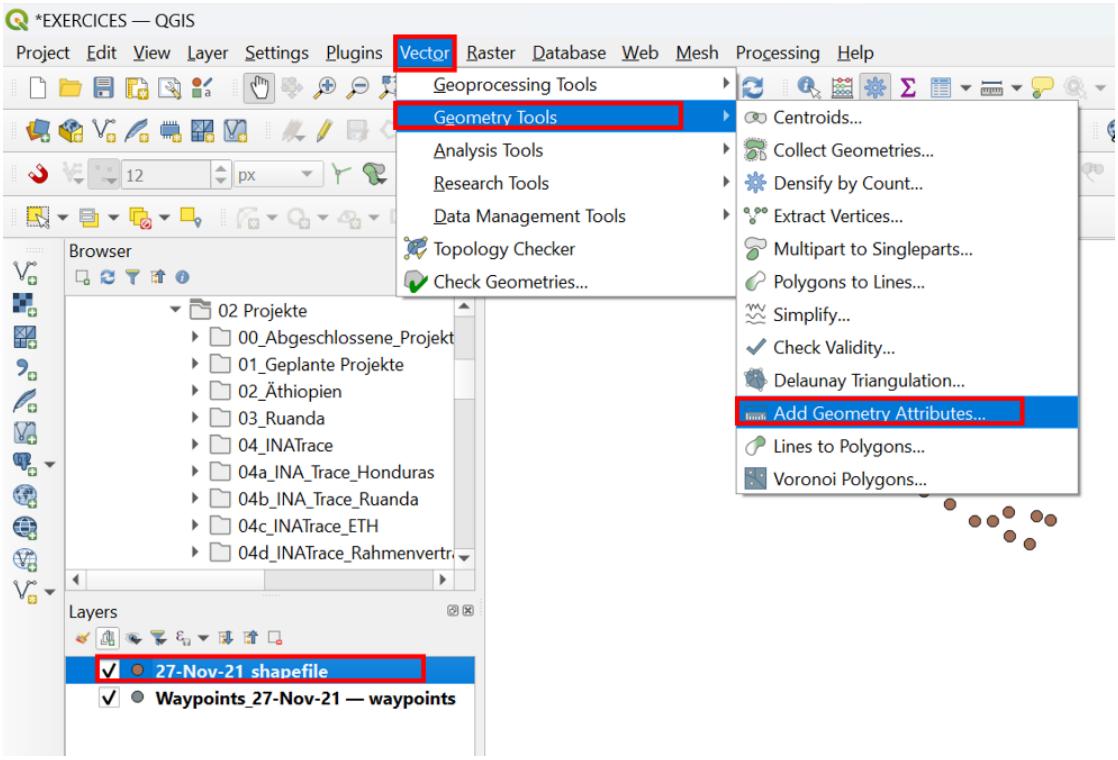
That being said, if we have to manipulate or correct a coordinate, we can do so in the attribute table. To do this, we first go into the attribute table to check whether our points have X, Y or Z coordinates listed in the table. To open the attribute table, right-click the GPS point data layer within the ***"Layers"*** panel and click  ***"Open Attribute Table"***.



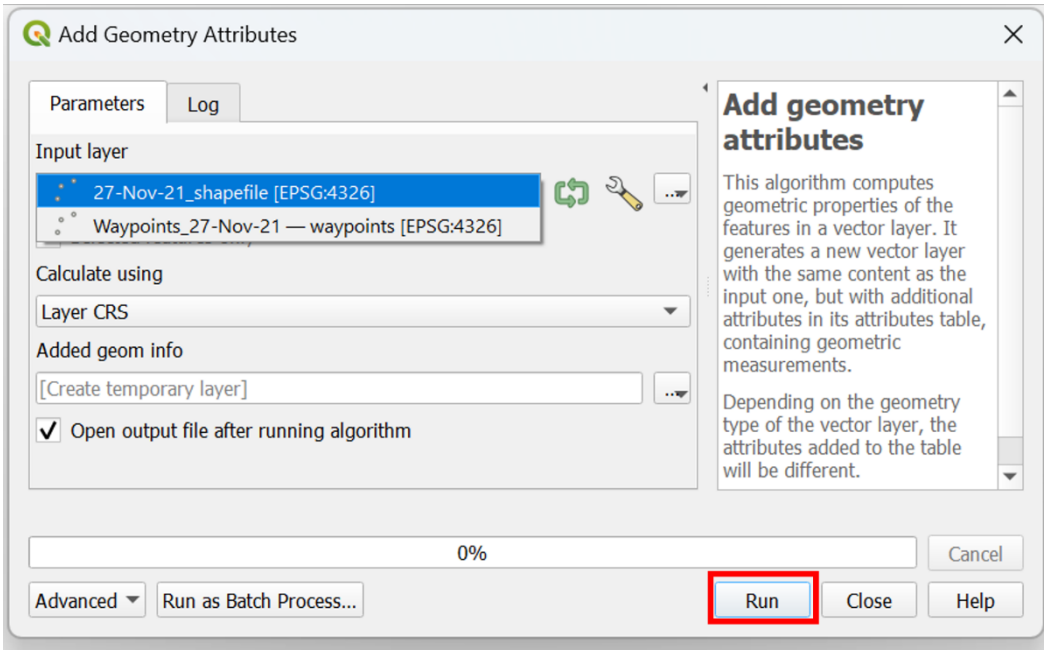
	ele	time	magvar	geoidheigh	name	cmt	desc	src	url
1	0	NULL	NULL	NULL	WP1	NULL	NULL	NULL	NULL
2	0	NULL	NULL	NULL	WP2	NULL	NULL	NULL	NULL
3	0	NULL	NULL	NULL	WP3	NULL	NULL	NULL	NULL
4	0	NULL	NULL	NULL	WP4	NULL	NULL	NULL	NULL
5	0	NULL	NULL	NULL	WP5	NULL	NULL	NULL	NULL
6	0	NULL	NULL	NULL	WP6	NULL	NULL	NULL	NULL
7	0	NULL	NULL	NULL	WP7	NULL	NULL	NULL	NULL
8	0	NULL	NULL	NULL	WP8	NULL	NULL	NULL	NULL
9	0	NULL	NULL	NULL	WP9	NULL	NULL	NULL	NULL
10	0	NULL	NULL	NULL	WP9	NULL	NULL	NULL	NULL
11	0	NULL	NULL	NULL	WP10	NULL	NULL	NULL	NULL
12	0	NULL	NULL	NULL	WP11	NULL	NULL	NULL	NULL
13	0	NULL	NULL	NULL	WP12	NULL	NULL	NULL	NULL
14	0	NULL	NULL	NULL	WP13	NULL	NULL	NULL	NULL
15	0	NULL	NULL	NULL	WP14	NULL	NULL	NULL	NULL

Browsing through the attribute table of our GPS data we cannot see any coordinate information. Therefore, we will automatically generate and add coordinates to the attribute table.

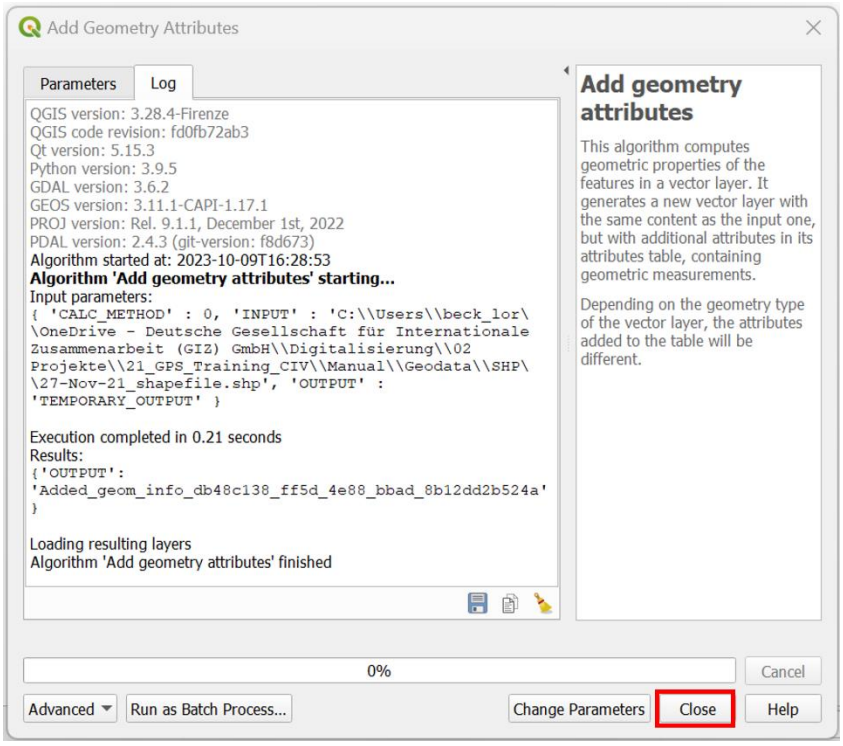
To do that, mark the shapefile layer within the *"Layers"* panel. Open the *"Vector"* menu at the top and navigate to *"Geometry Tools"* , then click *"Add Geometry Attributes"*.



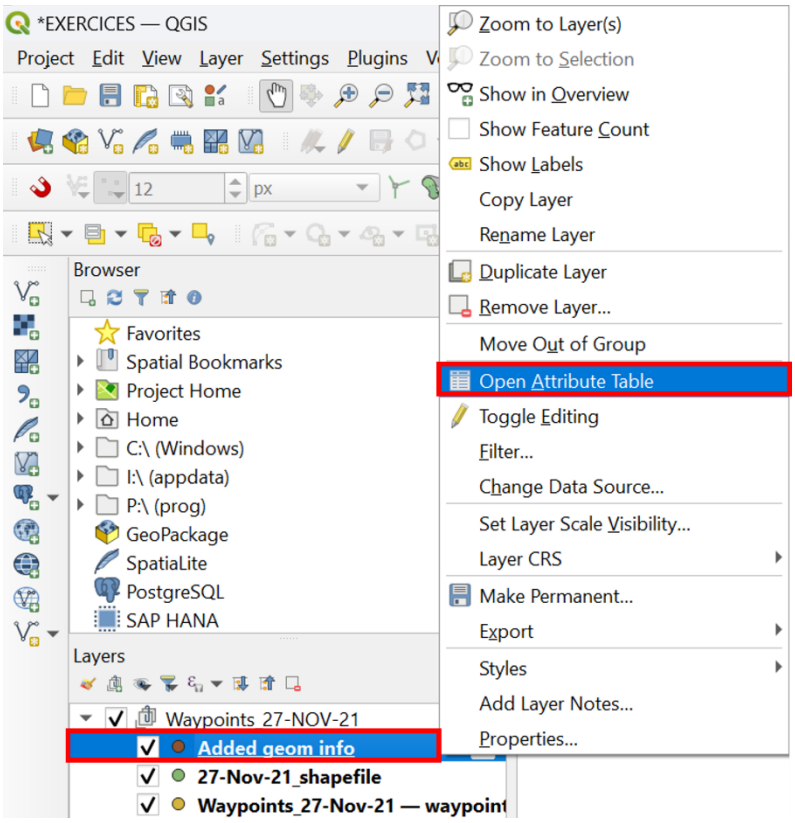
The dialogue box opens to run the function. Select the shapefile layer as input and click *"Run"*.



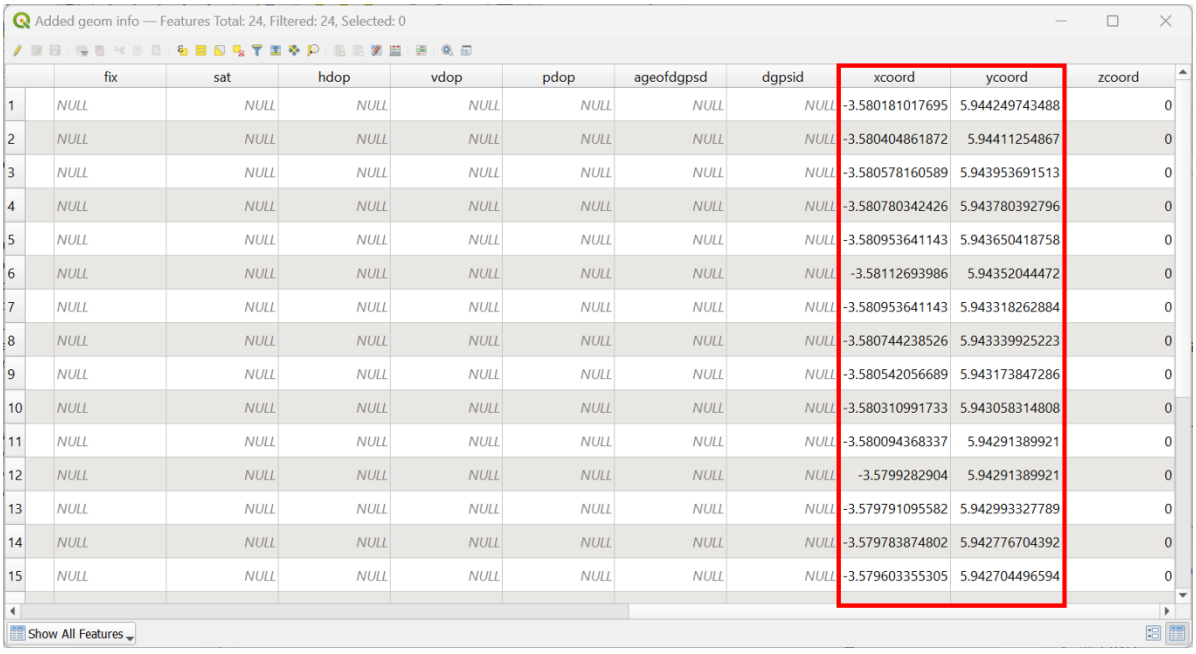
After the function has been executed, the Log frame gives an in-depth overview of the processing and the result status. If it says "*Algorithm … finished*", you can ***"Close"*** the box.



A temporary 'scratch layer' called ***"Added_geom_info"*** appears. To open its attribute table, right-click on this layer and select ***"Open Attribute Table"***



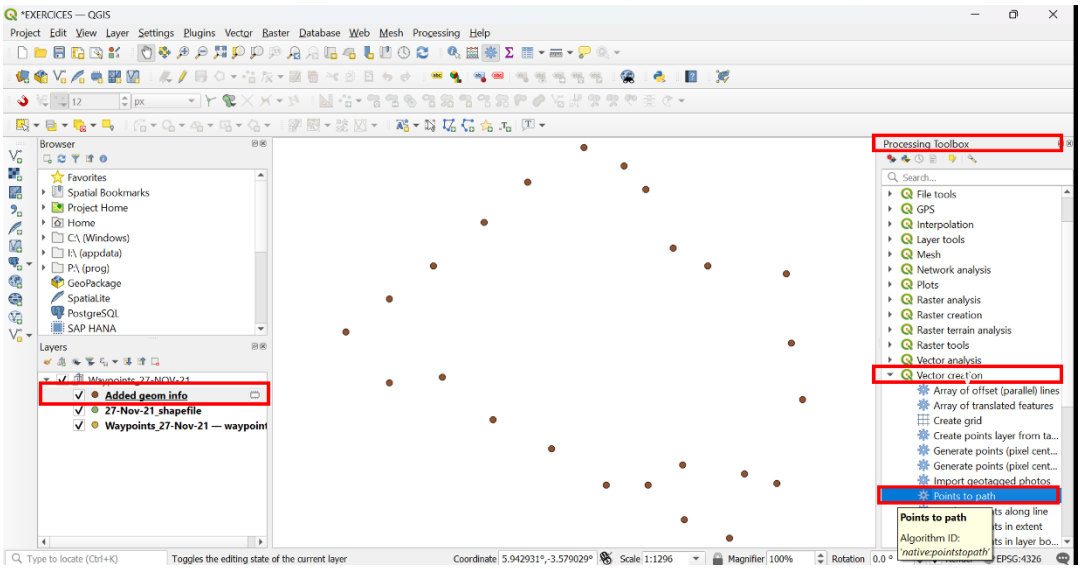
The attribute table now contains coordinate information for every point (row).



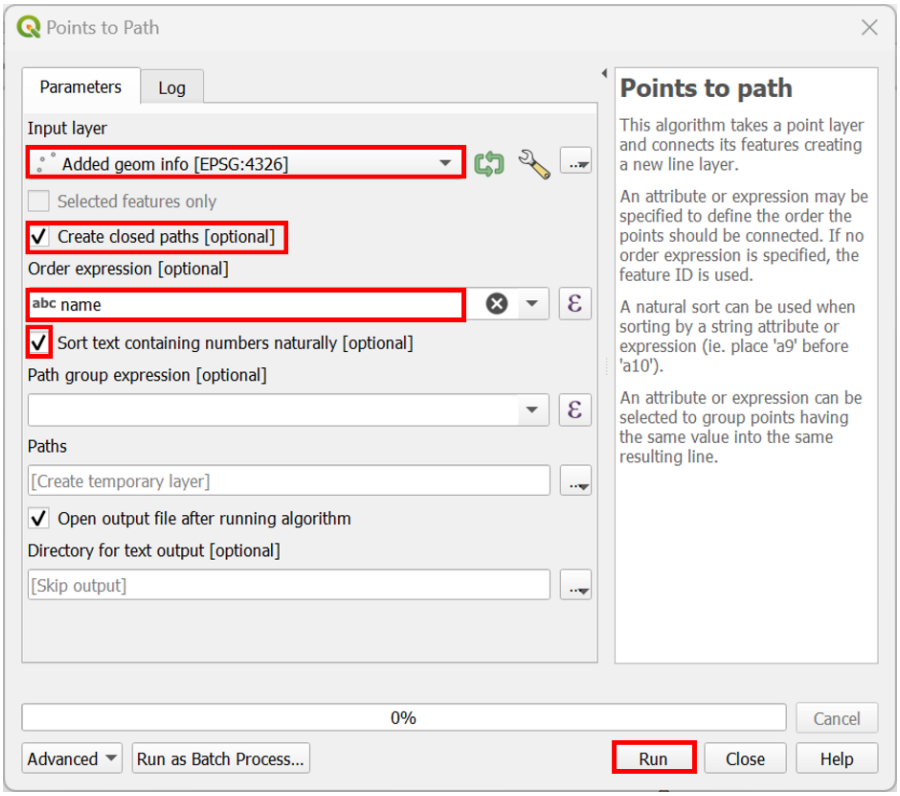
	fix	sat	hdop	vdop	pdop	ageofdgpsd	dgpsid	xcoord	ycoord	zcoord
1	NULL	NULL	NULL	NULL	NULL	NULL	NULL	-3.580181017695	5.944249743488	0
2	NULL	NULL	NULL	NULL	NULL	NULL	NULL	-3.580404861872	5.94411254867	0
3	NULL	NULL	NULL	NULL	NULL	NULL	NULL	-3.580578160589	5.943953691513	0
4	NULL	NULL	NULL	NULL	NULL	NULL	NULL	-3.580780342426	5.943780392796	0
5	NULL	NULL	NULL	NULL	NULL	NULL	NULL	-3.580953641143	5.943650418758	0
6	NULL	NULL	NULL	NULL	NULL	NULL	NULL	-3.58112693986	5.94352044472	0
7	NULL	NULL	NULL	NULL	NULL	NULL	NULL	-3.580953641143	5.943318262884	0
8	NULL	NULL	NULL	NULL	NULL	NULL	NULL	-3.580744238526	5.943339925223	0
9	NULL	NULL	NULL	NULL	NULL	NULL	NULL	-3.580542056689	5.943173847286	0
10	NULL	NULL	NULL	NULL	NULL	NULL	NULL	-3.580310991733	5.943058314808	0
11	NULL	NULL	NULL	NULL	NULL	NULL	NULL	-3.580094368337	5.94291389921	0
12	NULL	NULL	NULL	NULL	NULL	NULL	NULL	-3.5799282904	5.94291389921	0
13	NULL	NULL	NULL	NULL	NULL	NULL	NULL	-3.579791095582	5.942993327789	0
14	NULL	NULL	NULL	NULL	NULL	NULL	NULL	-3.579783874802	5.942776704392	0
15	NULL	NULL	NULL	NULL	NULL	NULL	NULL	-3.579603355305	5.942704496594	0

7.6 Transformation of points to lines

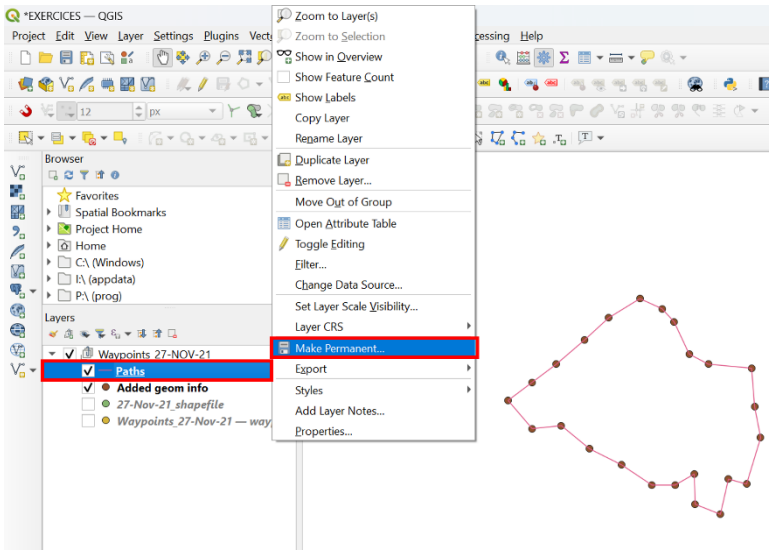
Select the shapefile layer > open the *"Processing toolbox"* panel **by pressing CTRL+ALT+T** > Unfold the *"Vector creation"* category > select the function *"Points to path"*



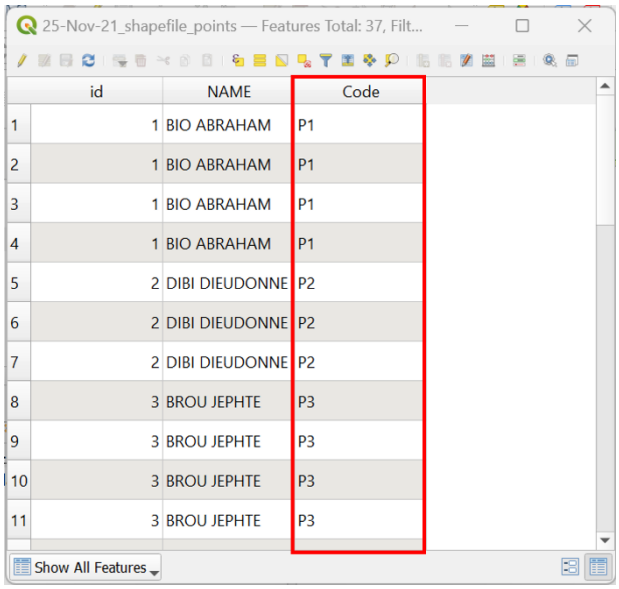
Select your shapefile as *"Input layer"* > tick the box *"Create closed paths"* > select a column from the attribute table that indicates in which order the points will be connected. In case these numbers are part of a text string (e.g. "WP1") tick *"Sort text containing numbers naturally"* > then *"Run"* > and *"Close"* after successful execution



A newly generated layer called *"Paths"* now shows a line (the only feature of the layer) connecting the points. This still is a temporary scratch layer. In case you want to save this layer into a file, right-click on the layer **>** select *"Make Permanent"*. Select 'Shapefile' as output format and set your preferred storage location.

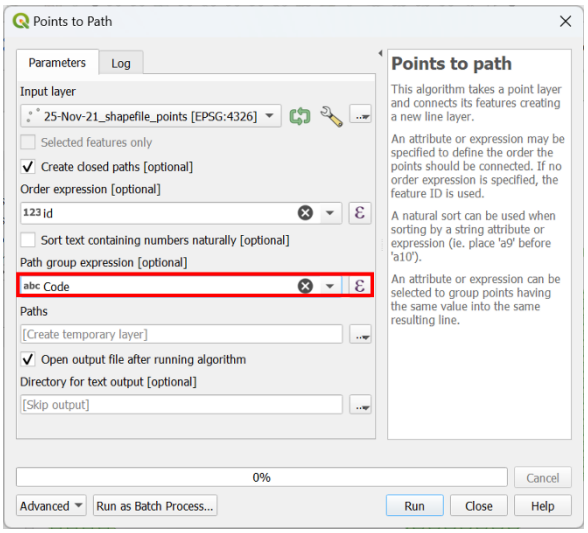


ATTENTION! Have you captured **several distinct polygons in the field and stored their waypoints all together in one common file?** Then we **must group the points** to clearly indicate which points belong to which polygon. Only then one line for each polygon is drawn. Otherwise, this function will simply connect all points to one single line.



	id	NAME	Code
1	1	BIO ABRAHAM	P1
2	1	BIO ABRAHAM	P1
3	1	BIO ABRAHAM	P1
4	1	BIO ABRAHAM	P1
5	2	DIBI DIEUDONNE	P2
6	2	DIBI DIEUDONNE	P2
7	2	DIBI DIEUDONNE	P2
8	3	BROU JEPHTE	P3
9	3	BROU JEPHTE	P3
10	3	BROU JEPHTE	P3
11	3	BROU JEPHTE	P3

To group the points, we need a **column/variable in the attribute table that indicates each point's affiliation to the corresponding polygon**. In this example below this is the column *"Code"* that indicates whether a point belongs to polygon 1 (P1), polygon 2 (P2), etc....

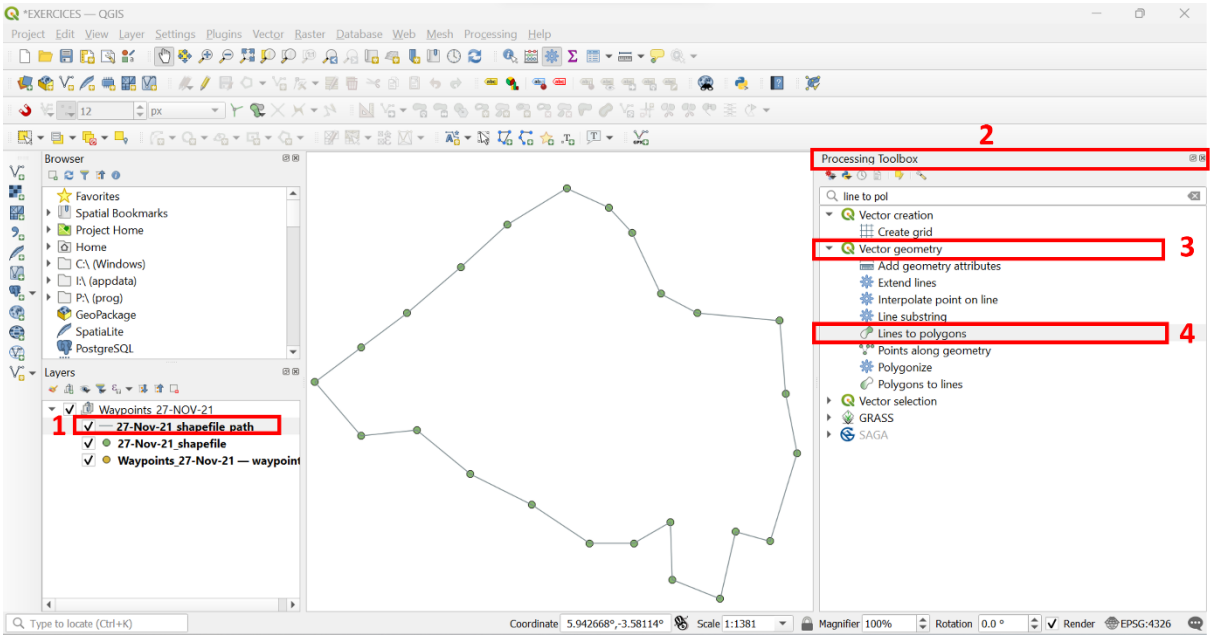


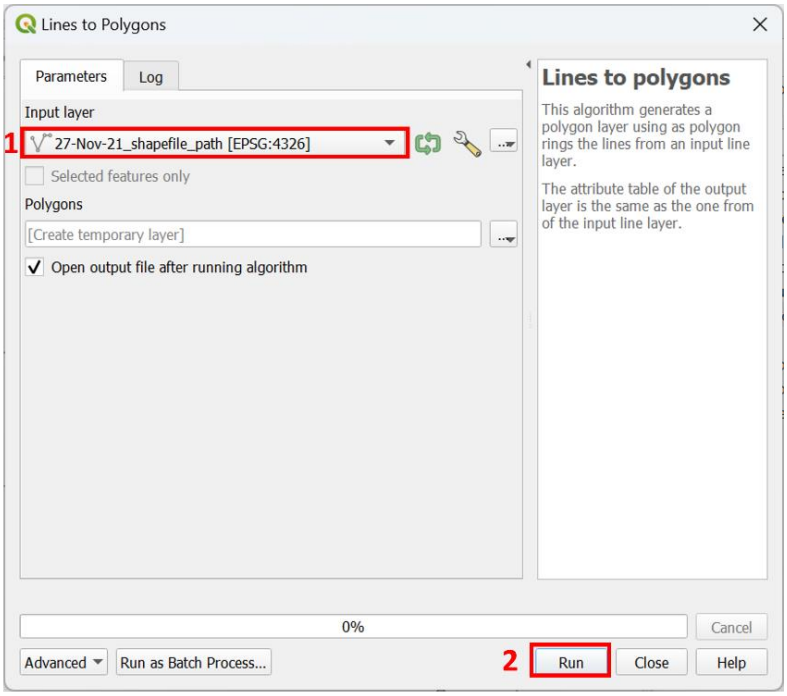
In the dialogue box of the function ***"Points to Path"*** you can now select the column indicating the affiliation at ***"Path group expression [optional]"*** besides the other settings (input layer, closed path, order expression). Now when you click 'Run' several lines will be created, one for each polygon.

7.7 Transformation of lines to polygons

In the previous step we have created one or several closed paths (in closed paths, the starting point is the same as the ending point). These are still stored as lines and not as polygons. Closed paths do not have an interior or exterior like a polygon and therefore no intersection checks could be performed, e.g., what field boundaries intersect with land classified as forest.

To transform a closed path line into a polygon, follow these steps: Select the path layer in the ***"Layers"*** menu (1) > go to the ***"Processing Toolbox"*** (2) unfold the ***"Vector geometry"*** section (3), and open the function ***"Lines to polygons"*** (4).

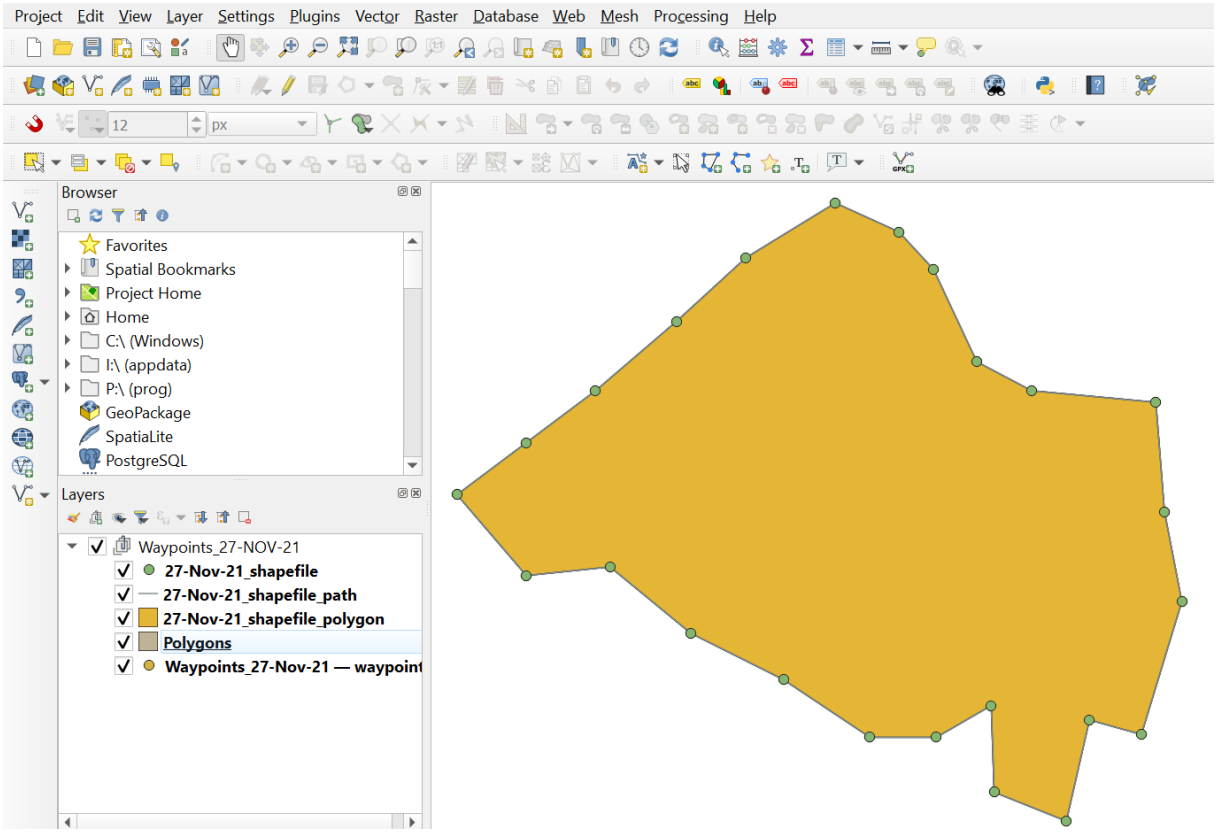




In the function's dialogue box, make sure the correct layer (the previously created closed path line) is inserted as the *"Input layer"*. Then click *"Run"* to execute the polygon creation.

You have now successfully created one or several polygons, which you can already recognize by the filled symbology in your map view.

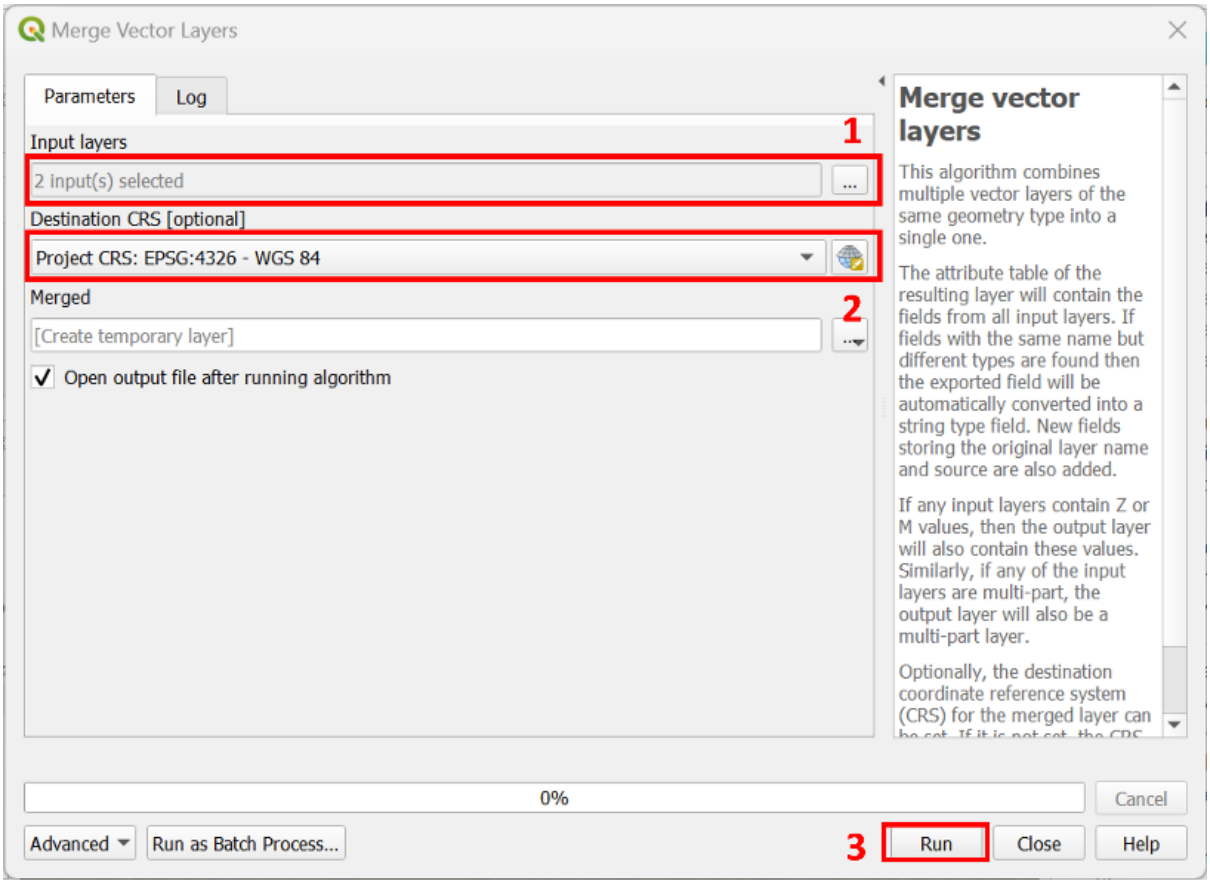
Be sure to make it a permanent file: Right-click on the layer **>** select *"Make Permanent"*. Select 'Shapefile' as output format and set your preferred storage location.



7.8 Merging single vector layers into one common layer

ATTENTION! In case you captured waypoints for **each polygon in a separate GPX file**, you will have to create single layers and ultimately a single file for each line or polygon transformed from the GPX data.

To aggregate single layers into a common layer, go to the *"Processing Toolbox" (CTRL+ALT+T)* > *"Vector general"* > and open the function *"Merge vector layers"*. Select the input layers you want to merge (1). You may want to set the CRS (2) which will be EPSG 4326 in most cases, however, this information is usually taken automatically from the input layers. On the right you find further information about the detailed processing. Click *"Run"* to execute the function and aggregate multiple layers/files into one layer/file. Note that you cannot merge layers of different geometry (such as points with lines or polygons)

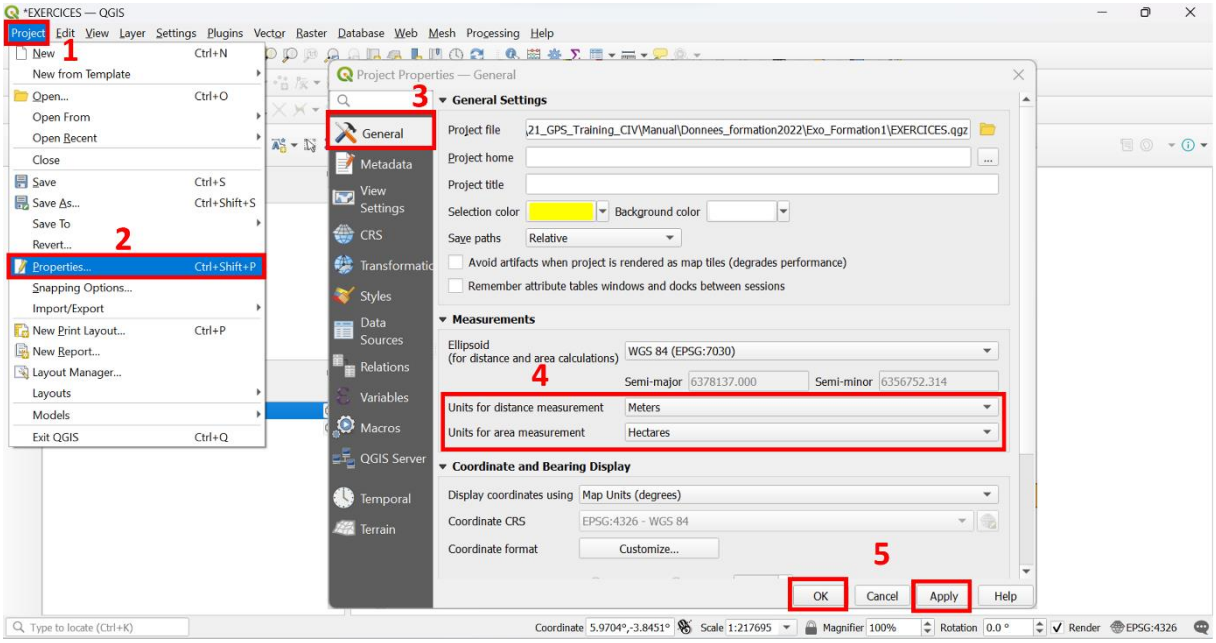


7.9 Calculate the area of polygons

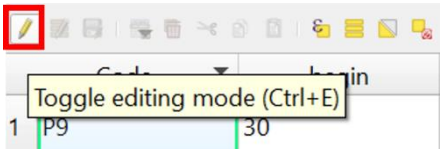
Before calculating the surface area of a polygon, you need to make sure that the unit of measurement is set correctly. As our GPS data have their coordinates stored in the CRS WGS84 (EPSG:4326), and therefore in degrees, we must ensure that the area is calculated based on metric geometries.

To do this:

1. Click on ***"Project"*** in the menu bar
2. Open the ***"Properties"***
3. Then, on the left open the tab ***"General"***
4. Under the subsection ***"Measurements"*** you can choose your preferrable unit at ***"Units for area measurement"*** as well as for ***"Units for distance measurement"***
5. ***"Apply"*** your changes and click ***"OK"***

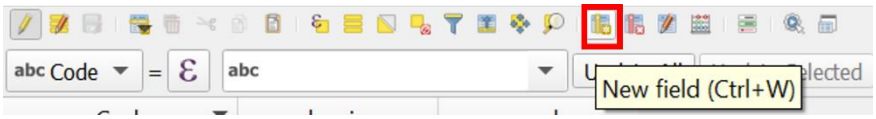


As the area/size of each polygon within one layer is a descriptive information, it belongs into the **attribute table**. We can add new variables as columns in the attribute table. To do that, first open the attribute table. Mark the layer within the ***"Layers"*** panel, and then either right-click on the layer and ***"Open Attribute Table"*** or click on the icon of the ***"Attribute Table"*** within the  toolbar at the top.



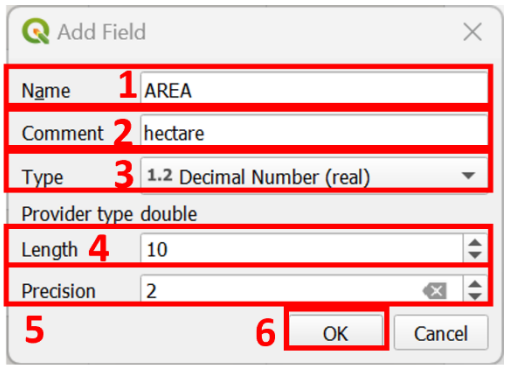
The attribute table opens and as we will subsequently edit the data, we have to activate the editing mode by clicking the yellow pen icon at the top left of the attribute table.

Now select the icon for adding a field  which you also find at the top.

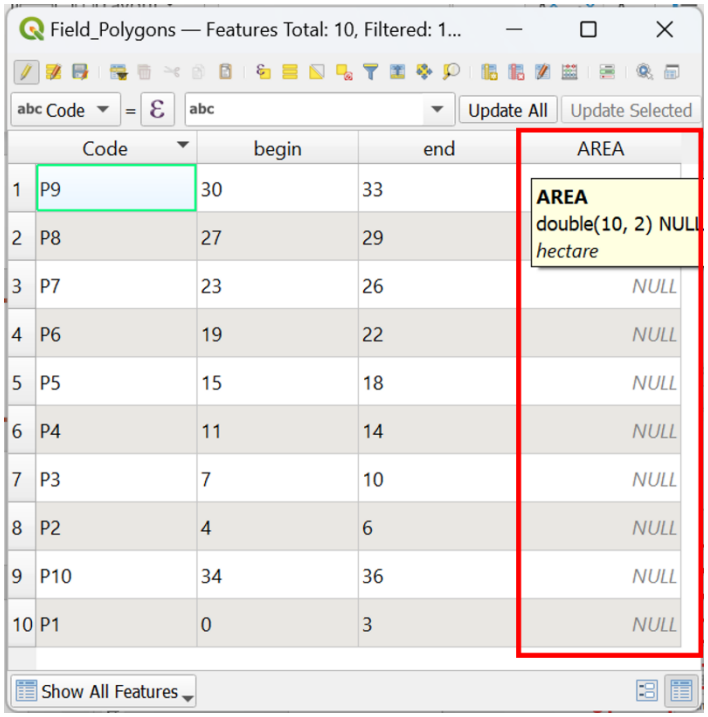


A dialogue box pops up for adding a new field. Fill in the following information:

1. Insert a suitable ***"Name"*** such as "AREA";
2. In the ***"Comment"*** field insert the measurement unit (e.g., in our case "hectare");
3. Select a suitable field data ***"Type"***. As we will store the area in numbers, we have to choose a quantitative data type, and as we also want to store decimals we choose ***"Decimal Number (real)"***.
4. Insert the maximum field ***"Length"*** (e.g., by default 10)
5. Set the ***"Precision"*** which refers to the number of digits after the comma (e.g., 2)
6. Click ***"OK"*** to add the field to the attribute table.

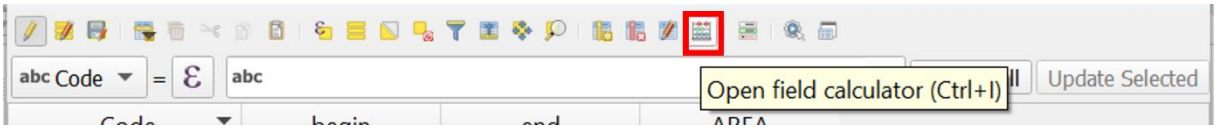


You can now see the added column ***"AREA"*** on the right of your attribute table. Hovering over the header of the column we also see its settings and the comment. Commented columns are



very useful for later users, especially the measurement unit for numerical information such as the area. However, so far there is no data stored within this column.

To feed the column with the automatically generated area we will use the ***"Field Calculator".*** You can directly open the "Field Calculator" from the attribute table by clicking on its icon at the top.

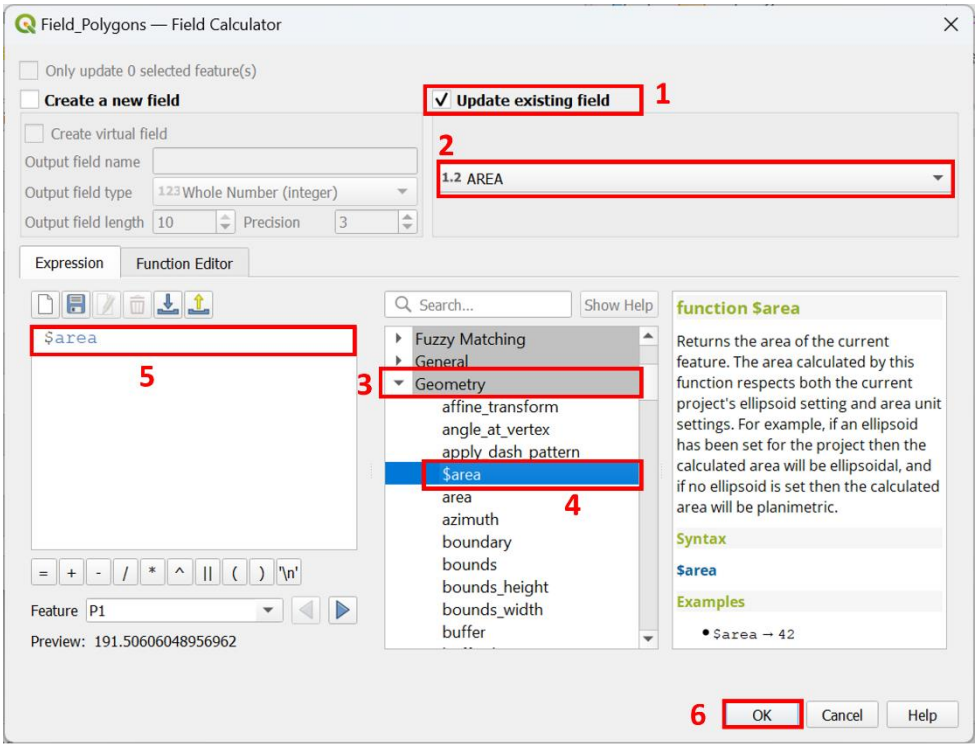


Alternatively, you can open the ***"Field Calculator"*** via a click on its icon within the ***"Attributes Toolbar"*** at the top.

The ***"Field Calculator"*** is used to modify existing fields or to create new fields based on expressions. To finally calculate the area, follow these steps within the dialogue box:

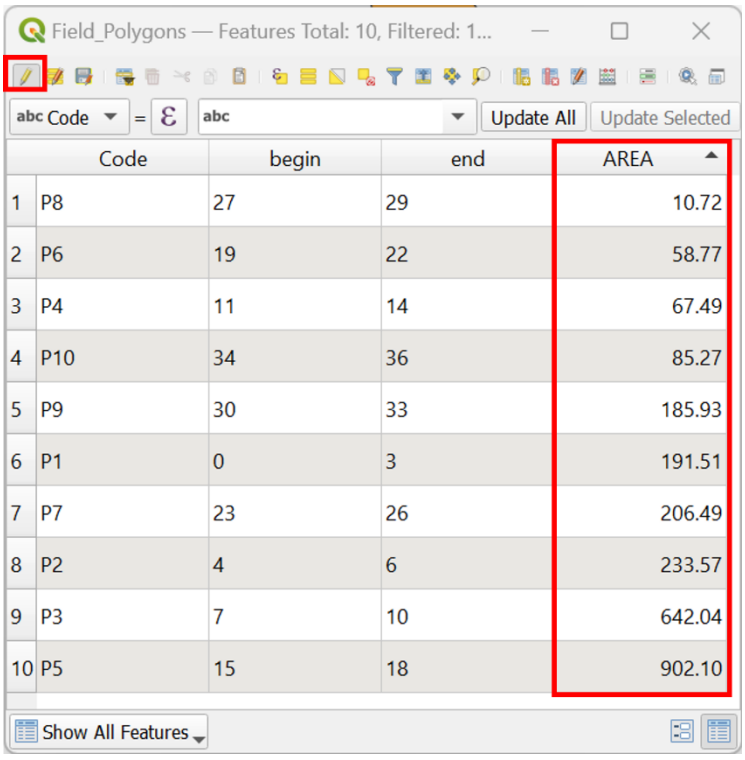
1. Tick ***"Update existing field"***;
2. Select your freshly created new field ***"AREA"***;
3. Now we can select the expression which will calculate the information for every polygon feature of the layer. There are a lot of useful functions for all kinds of calculations (for more information see QGIS documentation: Using the Field Calculator). For our purpose we unfold the ***"Geometry"*** options.
4. Here we double click on ***"$area"***, to calculate the area based on the measurement settings we have previously adapted. Attention: Don't mix it up with "area", as this won't respect the settings.
5. Through a double click the function is pasted into the ***"Expression"*** field. You can already see a preview of the results below the expression field.

6. Click *"OK"* to execute the area calculation.



https://docs.qgis.org/3.28/en/docs/user_manual/working_with_vector/attribute_table.html

With the execution of the function, the editing mode is directly activated. You can notice that by the editing symbol in front of your polygon layer within the *"Layers"* panel and by the highlighted editing mode in the *"Digitizing Toolbar"* on top. Before saving the changes, we first check the results of the area calculation.



	Code	begin	end	AREA
1	P8	27	29	10.72
2	P6	19	22	58.77
3	P4	11	14	67.49
4	P10	34	36	85.27
5	P9	30	33	185.93
6	P1	0	3	191.51
7	P7	23	26	206.49
8	P2	4	6	233.57
9	P3	7	10	642.04
10	P5	15	18	902.10

We can now see the new column called *"AREA"* within the attribute table, where for each polygon the area is shown in the selected measurement unit (here: hectares).

If everything appears correct, we can save the newly entered data by clicking on the toggle icon to deactivate the editing mode and confirm the saving.

VIII- MODULE 8: DIGITIZING GEODATA WITH QGIS

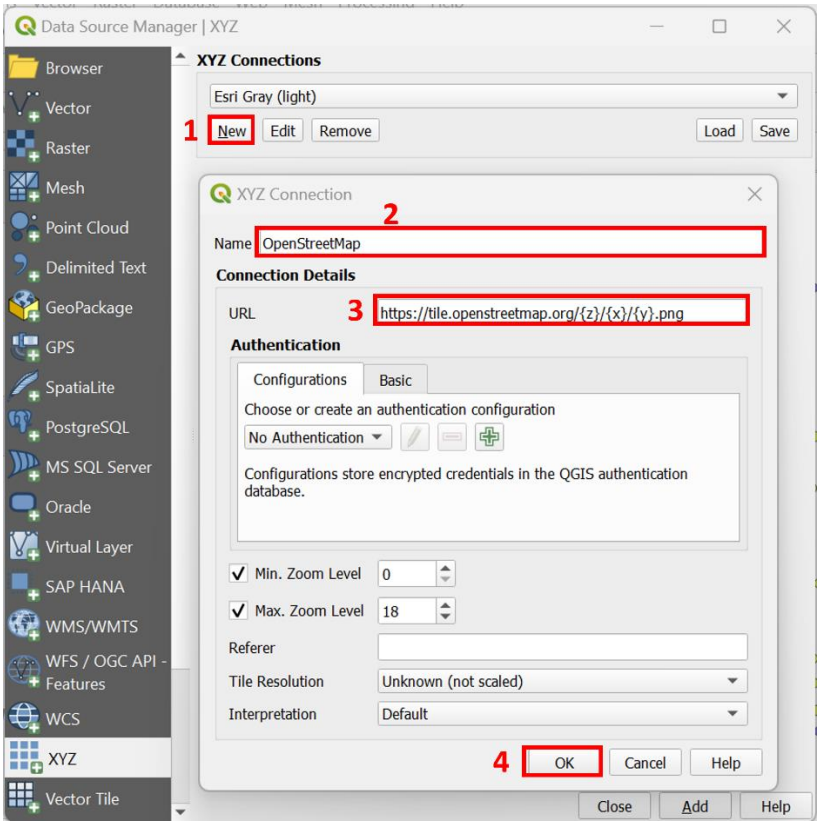
8.1 Purpose of the module

This module will show you how to insert basemaps into QGIS and use them for manually digitizing polygons, inserting attributes and saving them as shapefiles.

8.2 Adding background maps

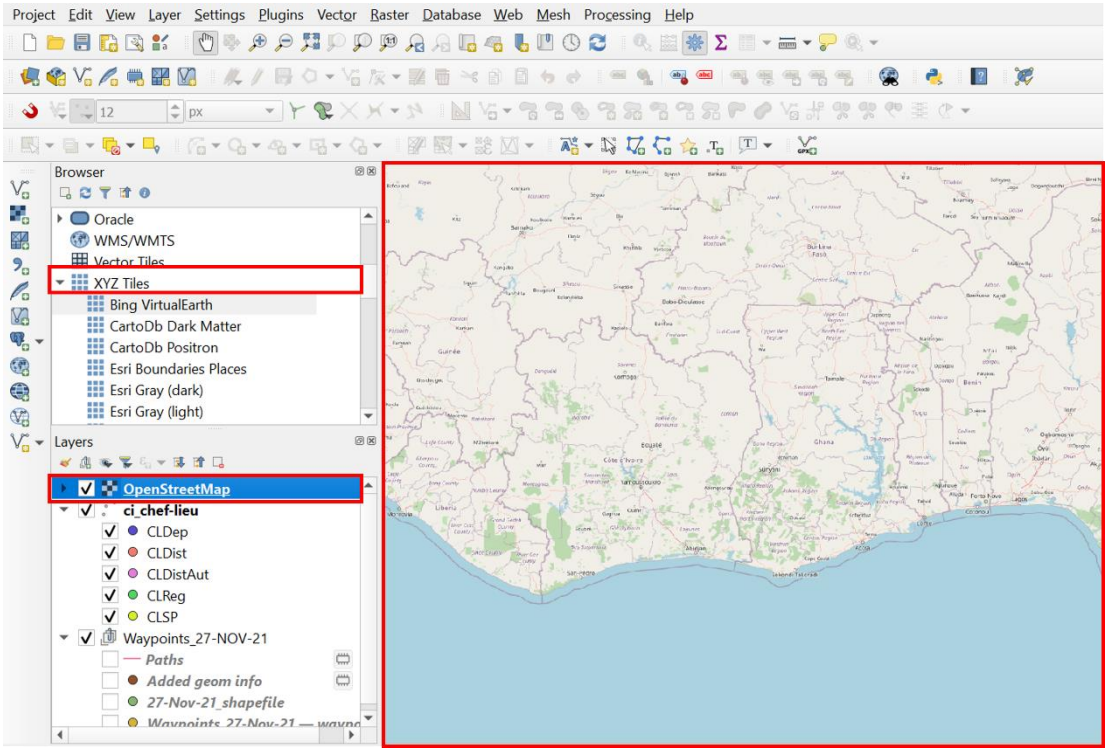
From the menu bar at the top unfold the *"Layer"* options > go to *"Add Layer"* and select *"Add XYZ Layer"*. Click on *"New"* to add a new connection (1).

- Add the name of the connection: OpenStreetMap (2)
- Add the URL (copy and paste to avoid errors!) (3)
  https://tile.openstreetmap.org/{z}/{x}/{y}.png
- Click *"OK"*: A new connection is now available!

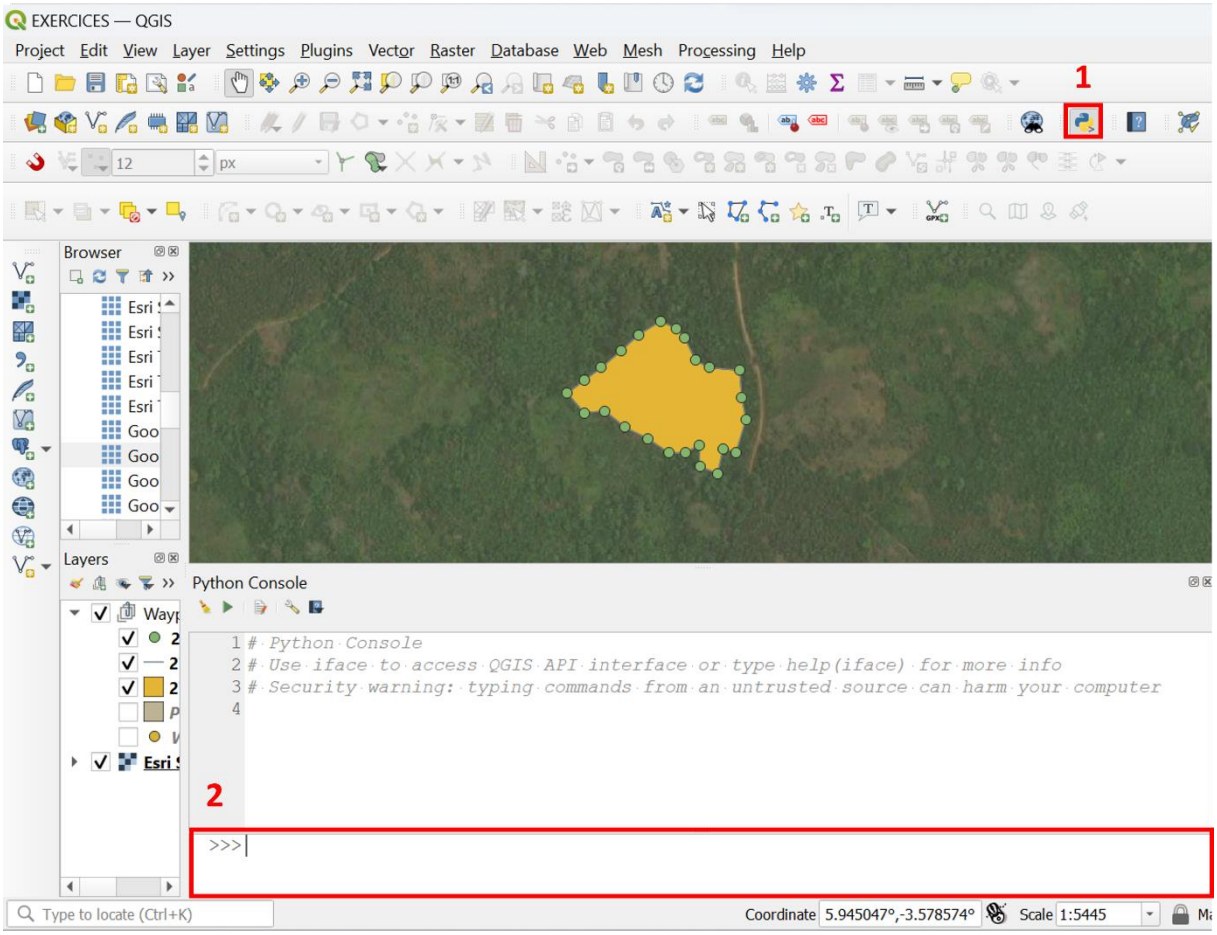


You can now select our established connection and click *"Add"* to add it to the map view.

Alternatively, you can use the *"Browser"* panel. Browse to *"XYZ Tiles"* > either double click on existing basemaps for adding them, or right-click on *"XYZ Tiles"* to add a new connection as described.



Besides thematic background maps (such as OpenStreetMap) there are also imagery basemaps (such as Google Satellite). Here is a link to a script that you can copy paste into the *"Python"* console within QGIS to add several basemaps at once. Open the *"Python"* console from the the toolbar at the top (1). Paste the copied script into the console (2) and press Enter to execute it. Now you should have more basemaps listed under *"XYZ Tiles"* in your browser panel (including imagery basemaps). Note that it is your responsibility to comply with each basemap's terms of use.



If you are registered for Planet NICFI data, there is also the ***"Planet Explorer"*** plugin for QGIS (https://developers.planet.com/docs/integrations/qgis/) that you can install and use to view monthly updated basemaps created from Planet satellite imagery over tropical areas.

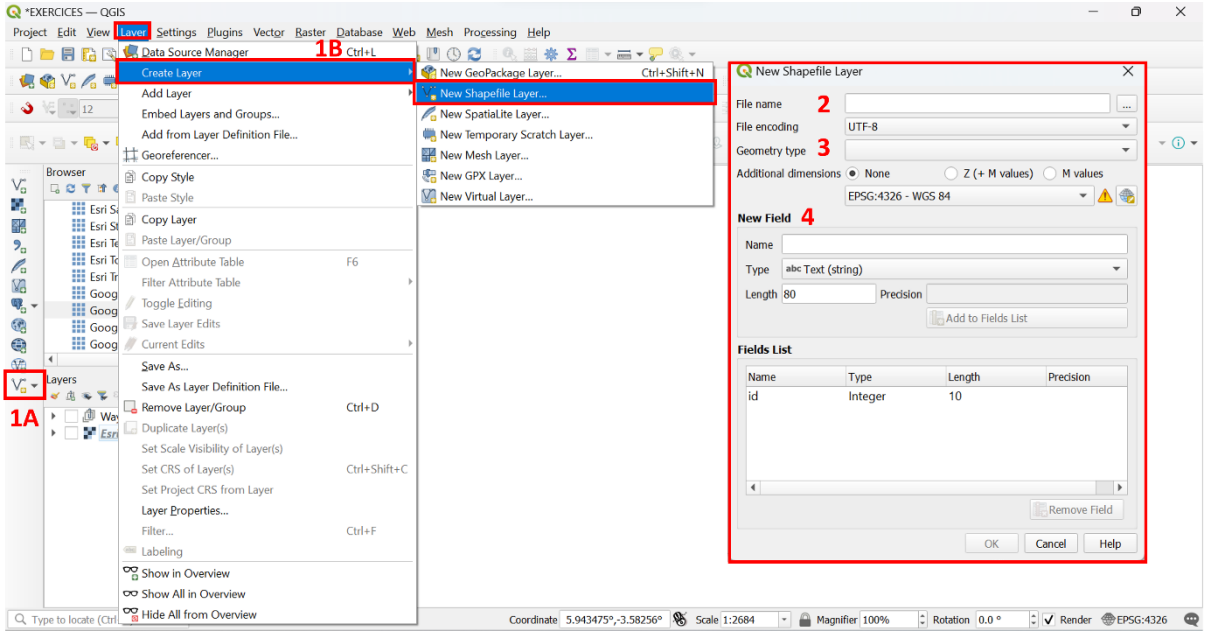
8.3 Digitizing polygons as shapefiles

You can also create polygons by **digitizing** them on the basis of high-resolution imagery. Be sure to know the exact source of your imagery, especially the acquisition time and accuracy, to create high-quality field boundary data.

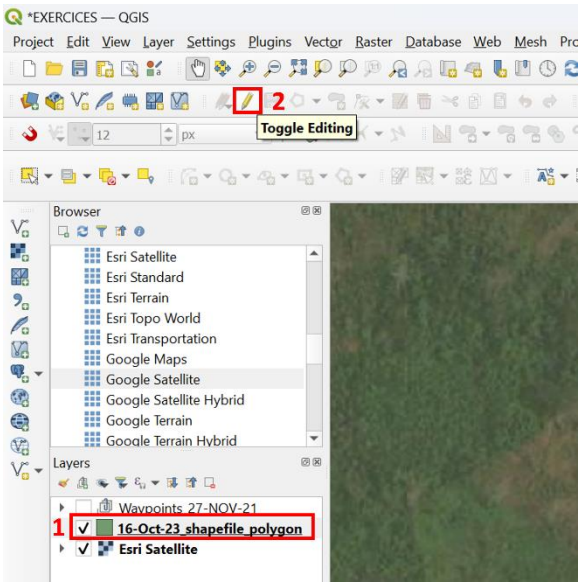
1. **Creation of an empty shapefile**

Create an empty shapefile either via the ***"Browser"*** panel on the left (1A) or via the ***"Layer"*** menu at the top > ***"Create Layer"*** > ***"New Shapefile Layer…"*** (1B).

Within the appearing dialogue box, give the file a name (2) and select a storage location by clicking the three dots next to the field. A geometry type (3), choose ***"Polygon"***. Under ***"New Field"*** (4) you can already pre-define columns for the attribute table, e.g., company internal IDs, names farmers, crop types, etc.… Click ***"OK"*** to create the empty shapefile.



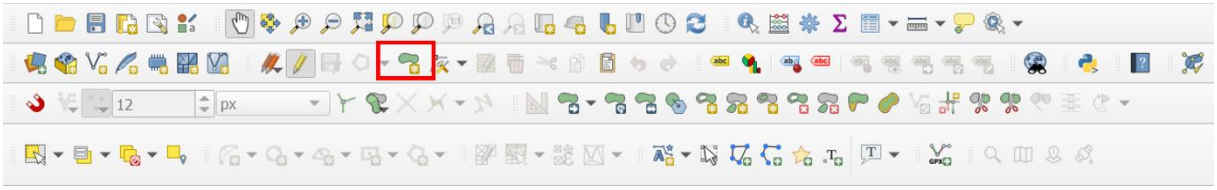
2. **Digitizing polygons into the shapefile**



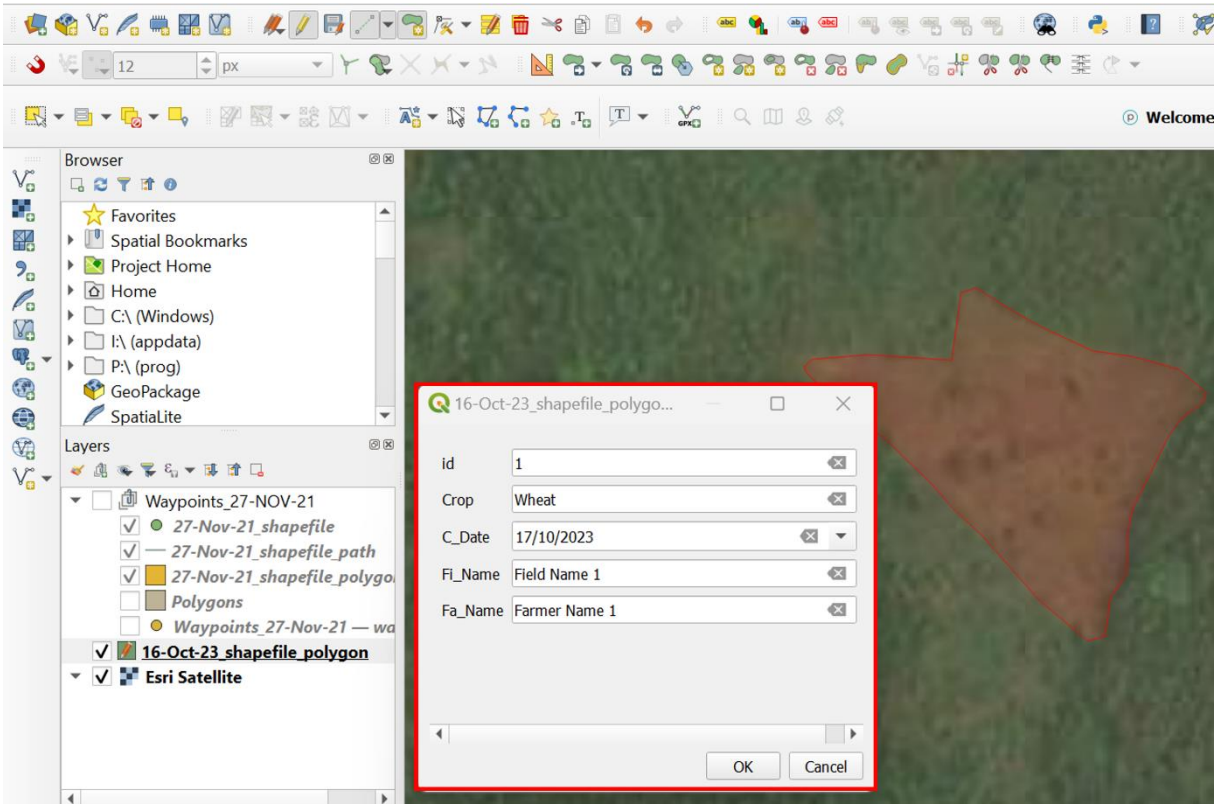
As you have now created an empty shapefile for polygons, you can fill this file by digitizing polygons based on the background imagery. To activate the editing mode, select the layer within the ***"Layer"*** menu (1) and click on the yellow pen at the toolbar on top (2).

When the editing mode is activated, some functionalities from the toolbar menu above are ready to be utilized now. Make sure you have activated at least the ***"Digitizing Toolbar"*** under the ***"View"*** > ***"Toolbars"*** menu. Besides more

advanced digitizing tools, the basic functionality to add simple polygons to your file is now ready to use.



Click on the icon  . (*Depending on your QGIS version, you might have to make sure that you are in the mode "Digitize with Segment", that you can select from a dropdown menu next to the icon.*) Start drawing with left clicks while each click creates a point/vertex that are combined to a closed polygon. If you want to delete a vertex, use the *"delete"* or *"backspace"* key on your keyboard. You can finish your geometry by right-clicking (QGIS Documentation 16.3.4.2 Editing - Adding Features). Afterwards, the dialogue box appears to insert the thematic data (attributes) that are linked to this field. Finally click on ***"OK"*** to save the feature to the layer.



You can now see the newly created polygon on the map and as a feature within the attribute table. You can repeat these steps to add more polygons to this layer.

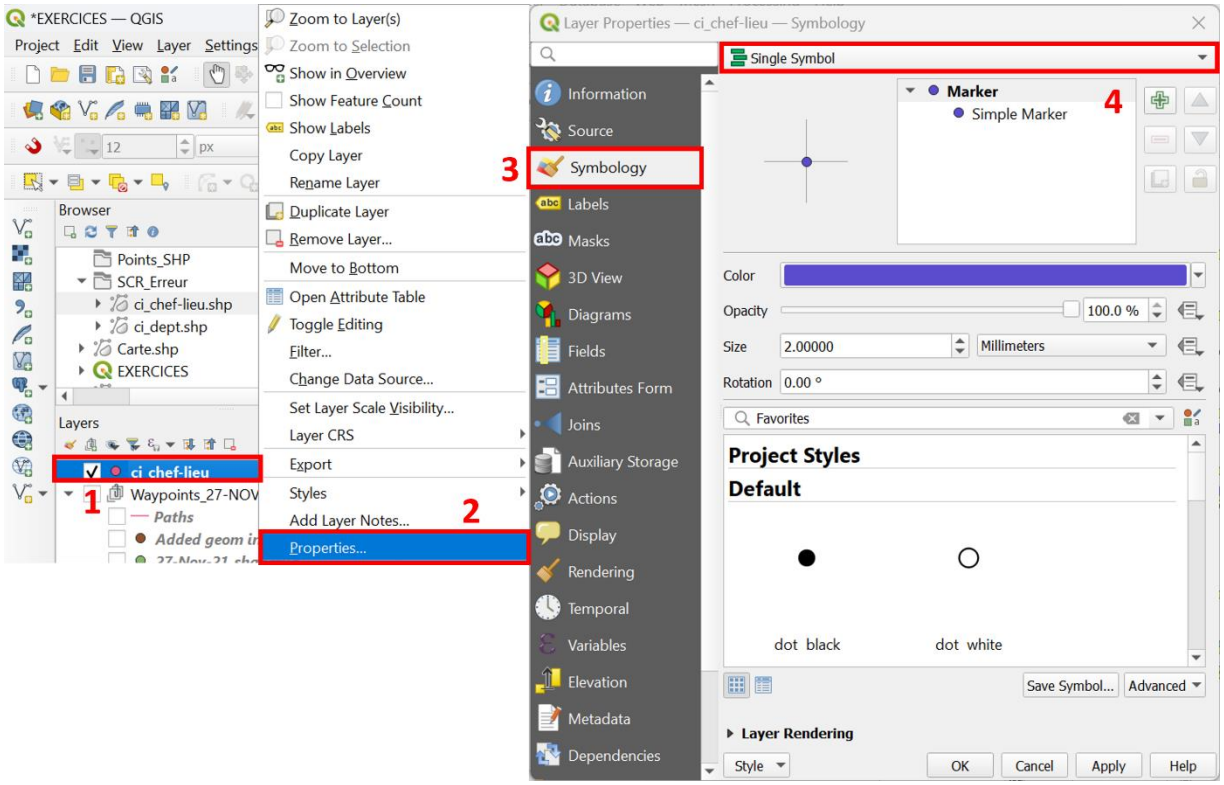
IX- MODULE 9: MAP VISUALIZATION & PRODUCTION IN QGIS

9.1 Modifying the symbology of a layer

Data symbology is a key element in representing data in an intuitively understandable way on a map through colours, colour gradients or palettes, symbols, etc. The use of labels often provides additional useful information (name or type of objects, values linked to objects, etc.).

To access all the symbology functions of a layer,

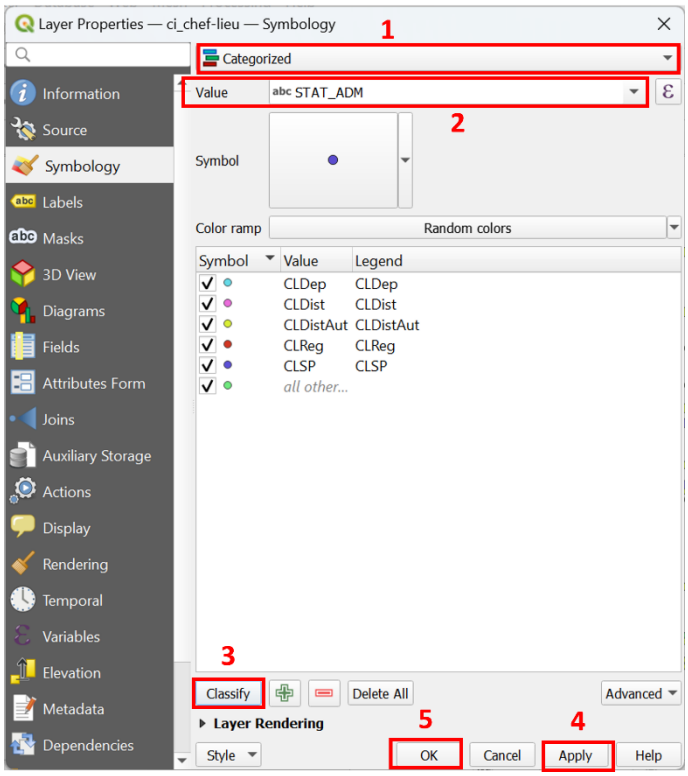
- Right-click on the layer name in the layer panel (1)
- Choose ***"Properties"*** (2). Within the new window switch to the tab ***"Symbology"*** (3).
- Choose the type of symbology best suited for your data (4)



Single Symbol

All objects are represented in the same way. Choose ***"Single Symbol"*** from the list at the top of the window, then set the colour (including line thickness, outline colour, fill type, etc.).

Categorized / Graduated



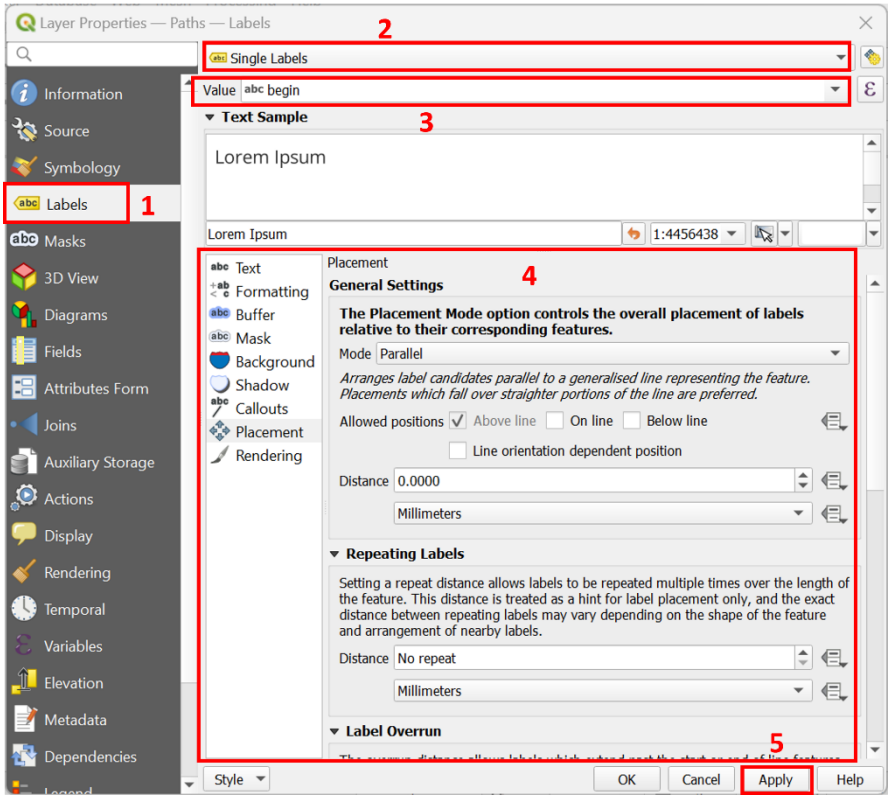
The objects are displayed differently depending on the values in the associated attribute table. Choose *"Categorized"* or *"Graduated"* (1) from the list. Categorized symbology is useful for discrete values (e.g., land use or crop types) and graduated symbology is best for continuous values (e.g., production amounts or vegetation density). Under *"Value"* (2), select the column containing the field values that will determine the visualization, then click the *"Classify"* (3) button. There are different possible classifications and you can create your own categories. All the values in a field can be differentiated. This mode can be used for both text and numeric values. To see the result, click *"Apply"* (4). You can experiment and find a symbology that you find suitable. When you are happy with the result, click *"OK"* (5).

ATTENTION! For the "Categorized" and "Graduated" symbology types, the symbology is based on the information contained in the attributes table. You must therefore:

- Define the column (in the "Value" menu) in the attributes table on which the symbology is based. It will sometimes be necessary to create the attributes in the attributes table on which the symbology will be based (16.2. Working with the Attribute Table — QGIS Documentation documentation).
- Don't forget to click the "Classify" button to create the desired symbology.

9.2 Adding labels

From the Layers panel, right-click the desired layer > select ***"Properties"*** and switch to the tab ***"Labels"*** (1). Select ***"Single Labels"*** (2), then for ***"Value"*** (3) indicate the field containing the values to be displayed. Set the font style to your preferences (4) and click ***"Apply"*** (5).



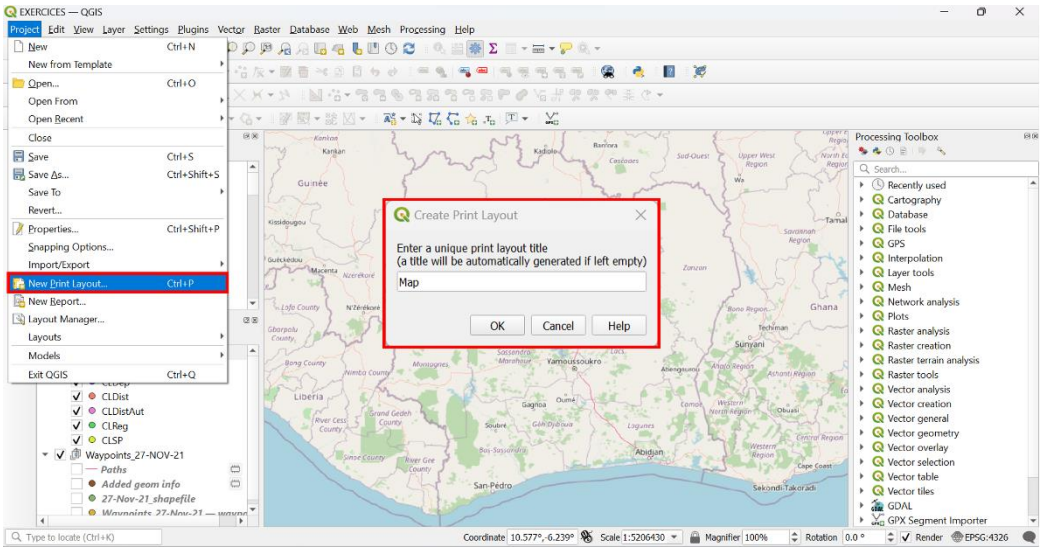
9.3 Map layout interface

Cartographic editing in QGIS is done in a ***"Print Layout"*** interface, which is a window independent of the main QGIS interface.

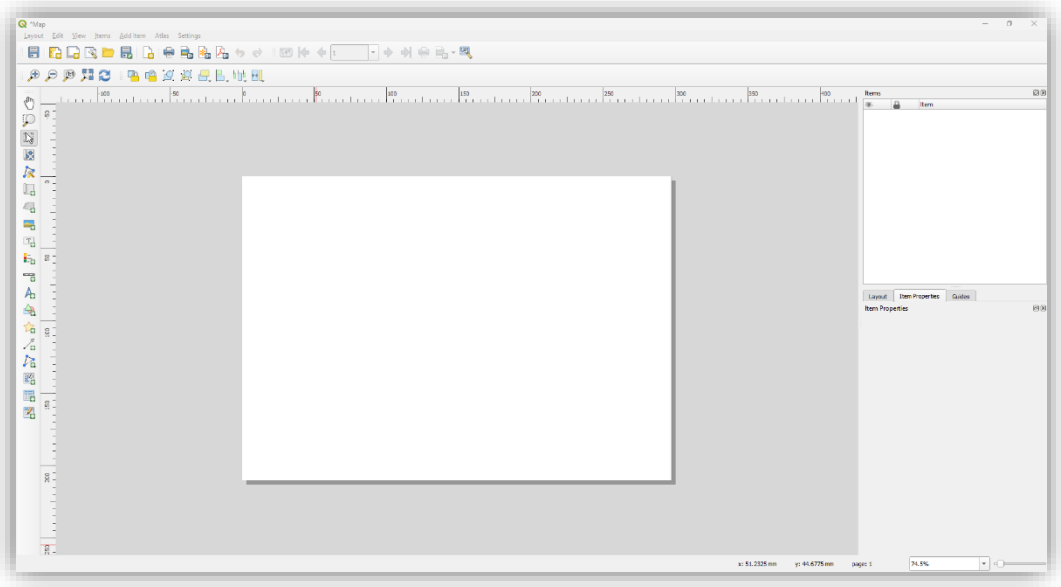
The layout interface is used to create and save/publish a single map layout. If several variants of the same map need to be created, then several layouts need to be created.

How to create a layout:

- Open **"Project"** from the menu bar **>** Click **"New Print Layout …»**
- Insert a title in the dialogue box popping up (or select "Page layout 1" by default)

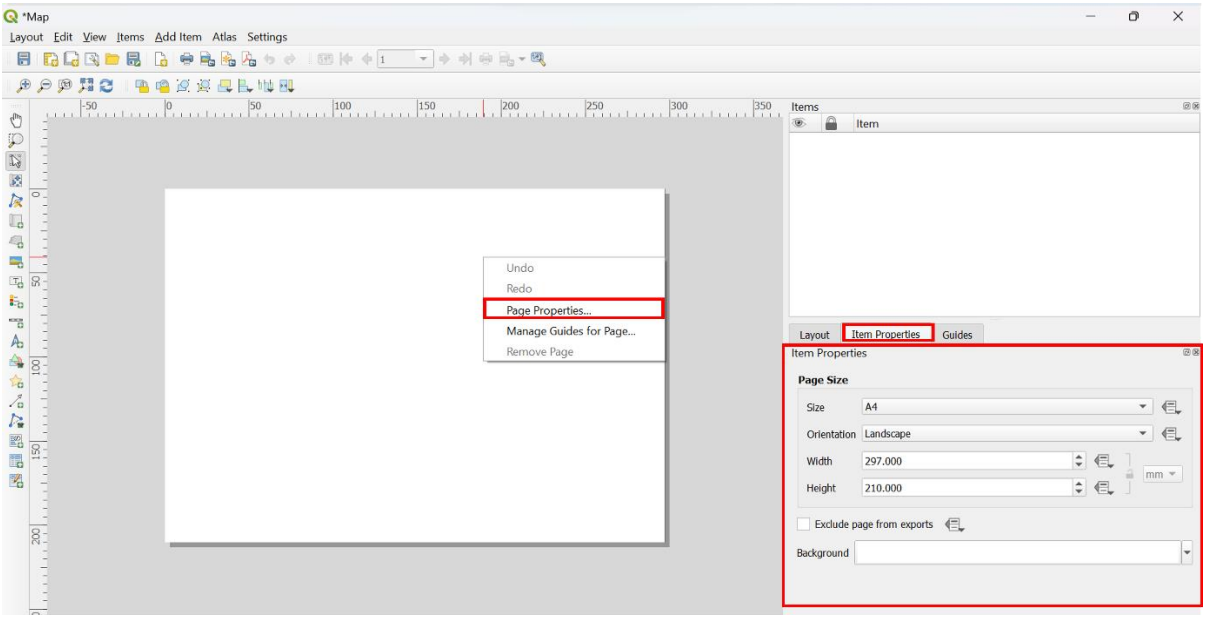


A blank page layout interface appears.



The size of the map (A4, A3, etc) and the "Portrait" or "Landscape" layout mode can be predefined:

- Right-click on the map > select **“Page Properties“** > navigate to the tab **“Item Properties”** > choose the size and orientation of your choice.



You can add several map items as listed below. Feel free to experiment and find the right layout. When you are done with the layout, you can export the map in different formats (PDF, regular image, SVG vector graphics.

"Map" items
Add Map
Add Picture
Add text (e.g., title, copyright)
Add Legend
Add Scale Bar
Add Shape
Add Arrow
Add Attribute Table
Add HTML Frame
Tools to Zoom
Tools for locking
Tools for grouping/ungrouping
Tools for aligning/repartitioning map elements
Export your map in different formats

9.4 Elements to appear on a map

Here's a list of the main elements to be included in a map, regardless of the theme.:

- Map title;
- A bar scale indicating the ratio of distances on the map to the real-world surface (digital scale if required);
- A legend;
- A north arrow;
- Author (person and/or "Company");
- Information on the Coordinate Referencing System (CRS) used (name of coordinate system and datum);
- Map creation date;
- Sources and dates of data used to create the map;

Other useful elements to add

- Neighboring map references (if your map is part of a set of adjoining maps)
- A geo-referencing grid or graticule;
- A bounding rectangle

Note: A map should not be overloaded; the colours used must allow the map to be readable and understandable (use the *"Preview"* mode under the menu item *"View"*); fonts must be visible and legible.

X- MODULE 10: SUSTAINABLE MANAGEMENT OF NATURAL RESOURCES

10.3 Purpose of the module

This module addresses sustainability, monitoring and traceability. By analysing your data, you may find plots that are in illegal areas such as classified forests, reserves, etc. (Advice: Check if governmental open data platforms are available with data on land use or forest geodata (e.g. WHISP).

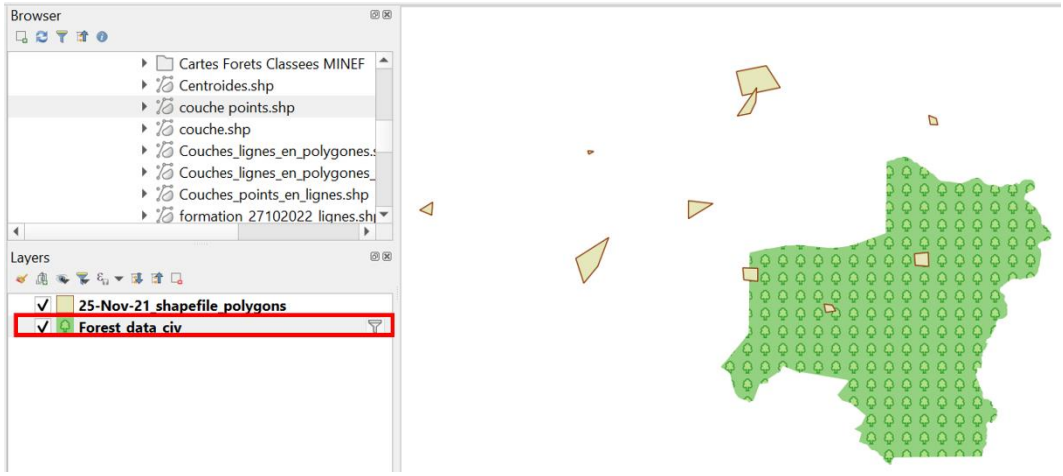
By doing these analyses, you can detect problematic plots and other potential difficulties early in order to anticipate them.

10.4 How to detect plots in illegal areas?

After the collection of waypoints in the field and its transformation to polygons, this work is carried out downstream to check the quality of the work carried out by the agents in the field and to assess the location of fields compared to other geospatial data, such as forest data.

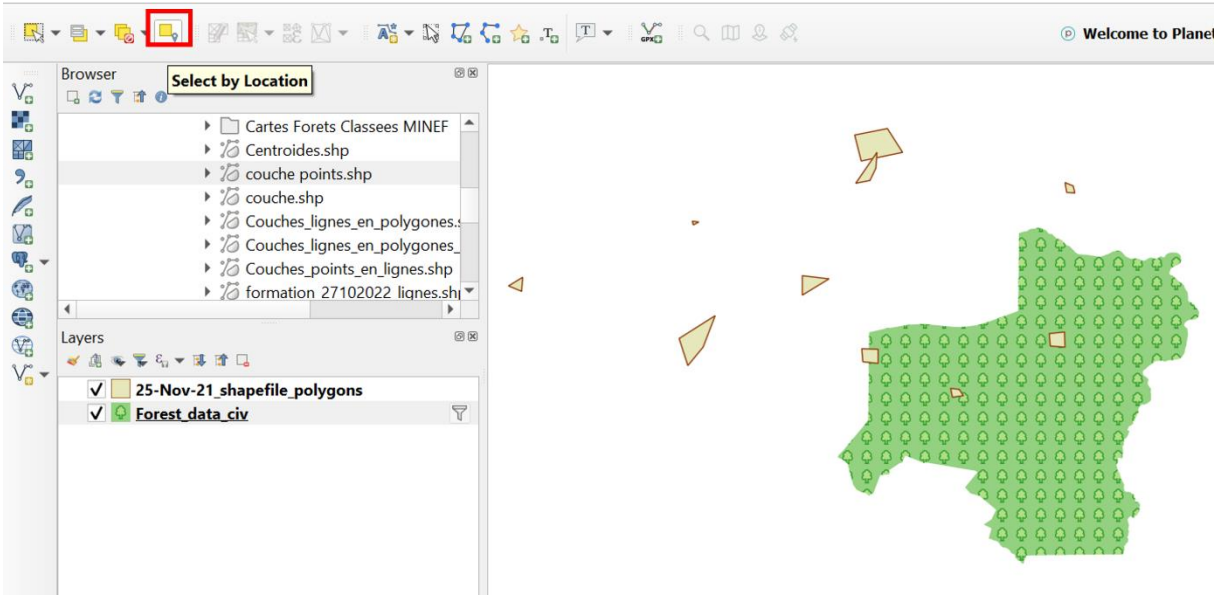
- Display **points, lines or polygons** of parcels **in QGIS** (in this case points):

- **Add a layer with classified forest area,** and drag it to the bottom in the ***"Layers"*** panel. You can use a filter (right-click > ***"Filter"***) on the available attributes (e.g., forest type) to only display distinct features of the layer.



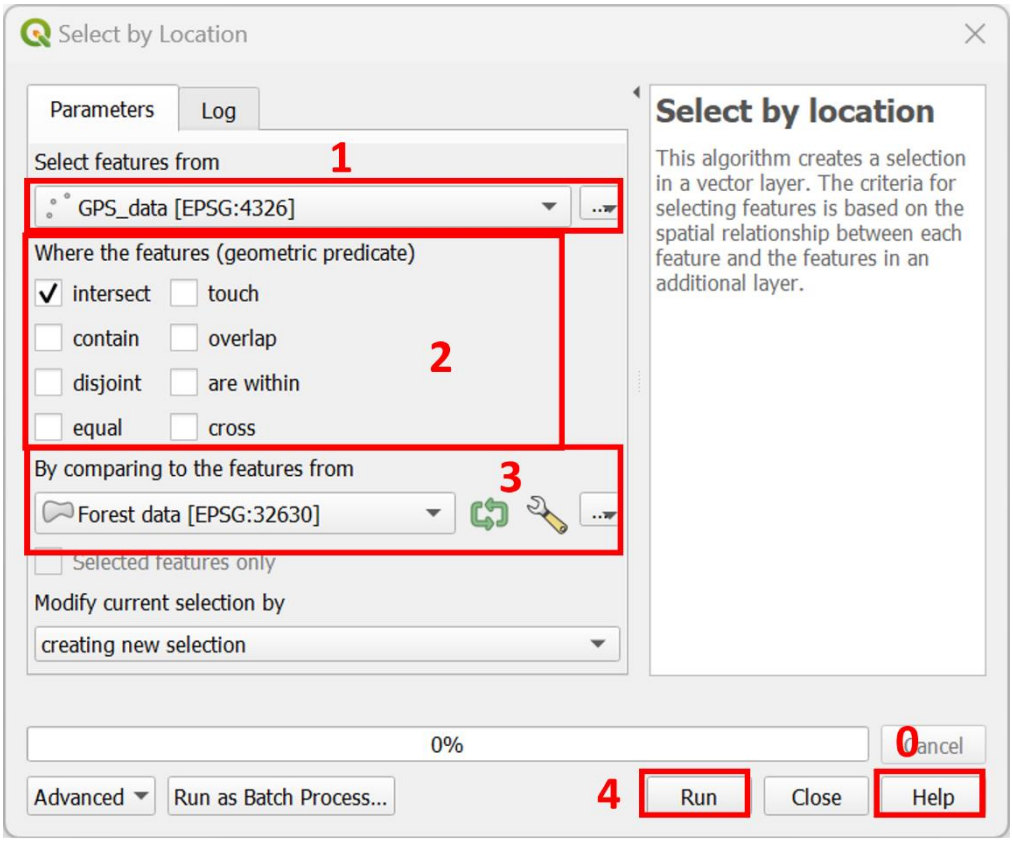
❖ **Identify points, lines or polygons** that are **located INSIDE of the classified forests.**

Click *"Selection by Location"* within the *"Selection Toolbar".*



The dialogue box for selecting features by location pops up.

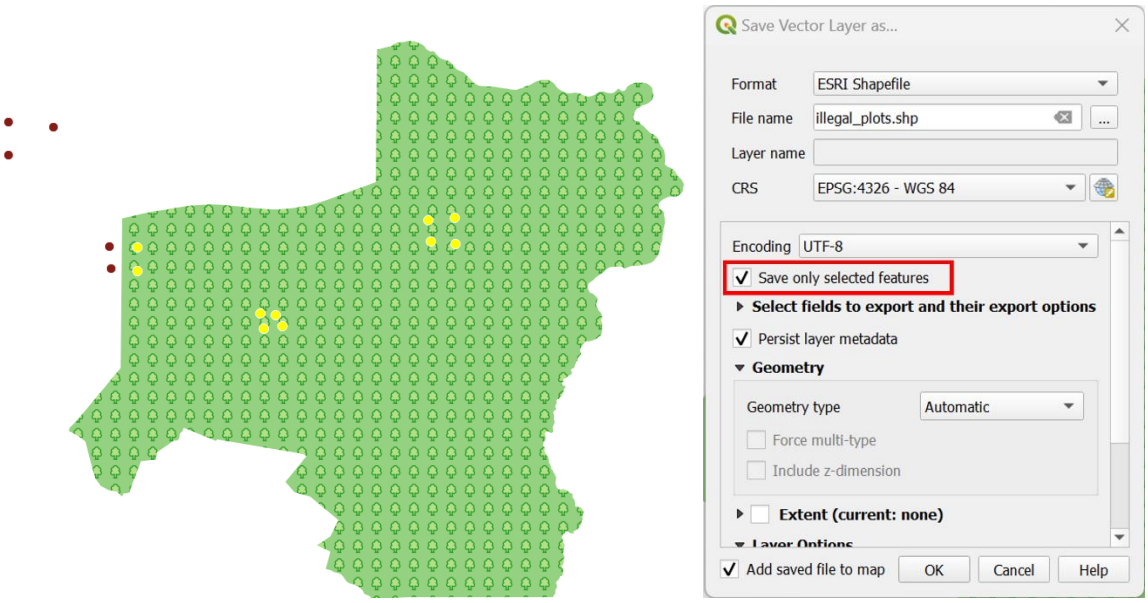
Generally, you can always click on the *"Help"* button (0) of each function, that redirects you to the QGIS documentation. In this case you get more details about the process here.



1. Under ***"Select features from"***, choose the layer from which you want to select (identify) the features. In our case this would be the GPS data layer that we created in previous chapters.
2. Choose the ***"Where the features (geometry predicate)"***. These are rules for comparing the input features' geometric location to the geometries from the *"base-comparison"* layer. Use the ***"Help"*** button to see examples of each geometrical predicate. In our case we choose ***"intersect"*** which means that all GPS points are selected that in any way intersect with the forest polygon (i.e., touch, or are within the forest polygon).
3. Choose the ***"By comparing to the features from"*** layer, which means that the selected rule (geometric predicate) compares features from the input layer to this layer. In our case this would be a forest polygon from another source.
4. Click "Run" to find out which GPS points intersect with the forest polygon.

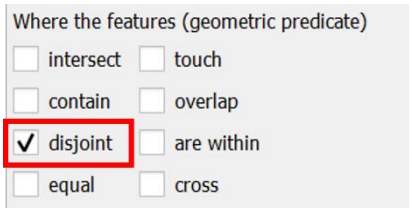
❖ **The selected GPS points, lines or polygons** are now highlighted yellow on your map.

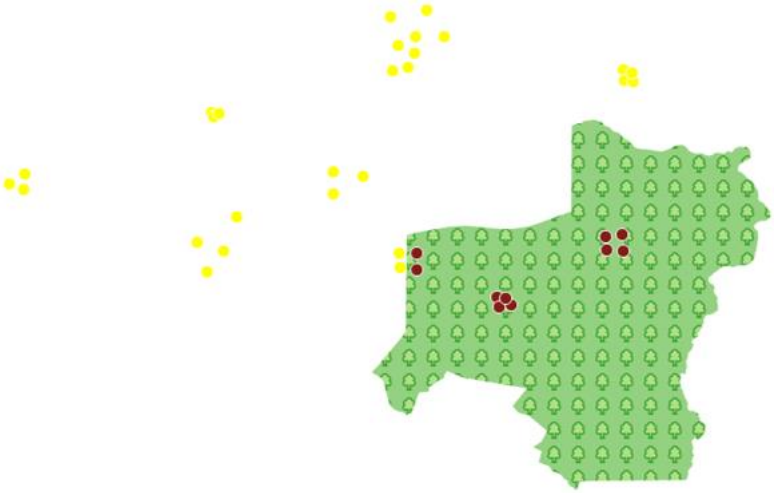
This indicates that these points/features are **actively selected within the point layer**. In case you want to export only these points, lines, or polygons you can right-click on the layer > select ***"Export"*** > ***"Save Features As".*** Within the window that pops up, make sure to tick ***"Save only selected features"*** and select a storage location.



❖ **Identifying waypoints** that are **located OUTSIDE of the classified forests.**

Follow the previous steps but instead of choosing ***"intersect"*** as geometric predicate choose ***"disjoint"***.

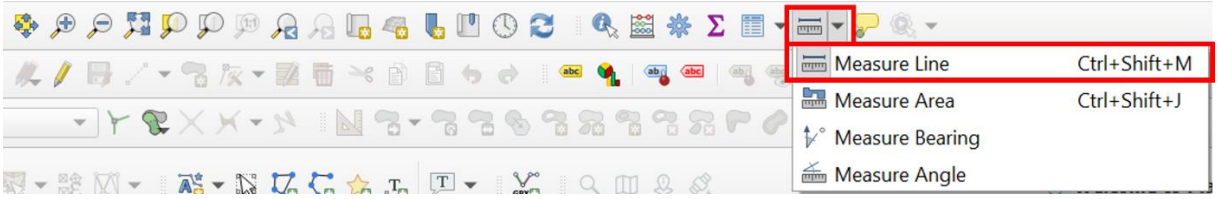


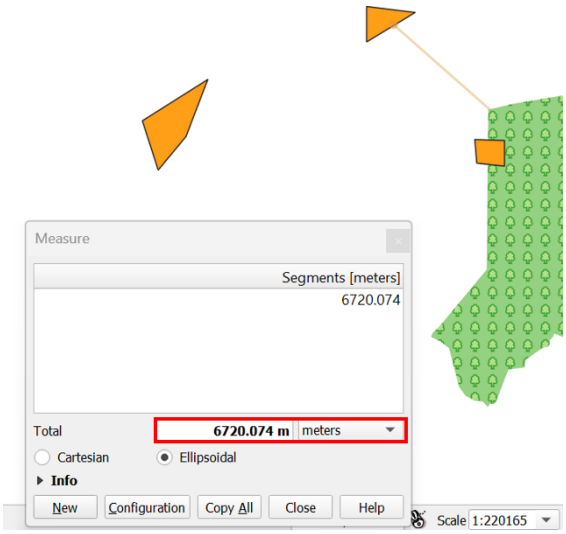


10.5 Measuring distances between two objects in QGIS

The aim here is to measure the distance between two objects. If we have plots of land that are at a certain distance from classified forests, we can measure them ourselves in order to avoid trade refusals caused by new regulations.

Click on the ***"Measure Line"*** tool at the top within the ***"Attributes Toolbar".*** Make sure to measure a line, by clicking on the dropdown and selecting ***"Measure Line"***.





Using the measuring tool, left-click on the **starting location** and then left-click again on the **ending location** on the map. Within the dialogue box you can already see the measured length varying dynamically. To freeze the measurement, right-click.

XI- MODULE 11: FROM THE OFFICE TO THE FIELD (FROM QGIS TO GPS)

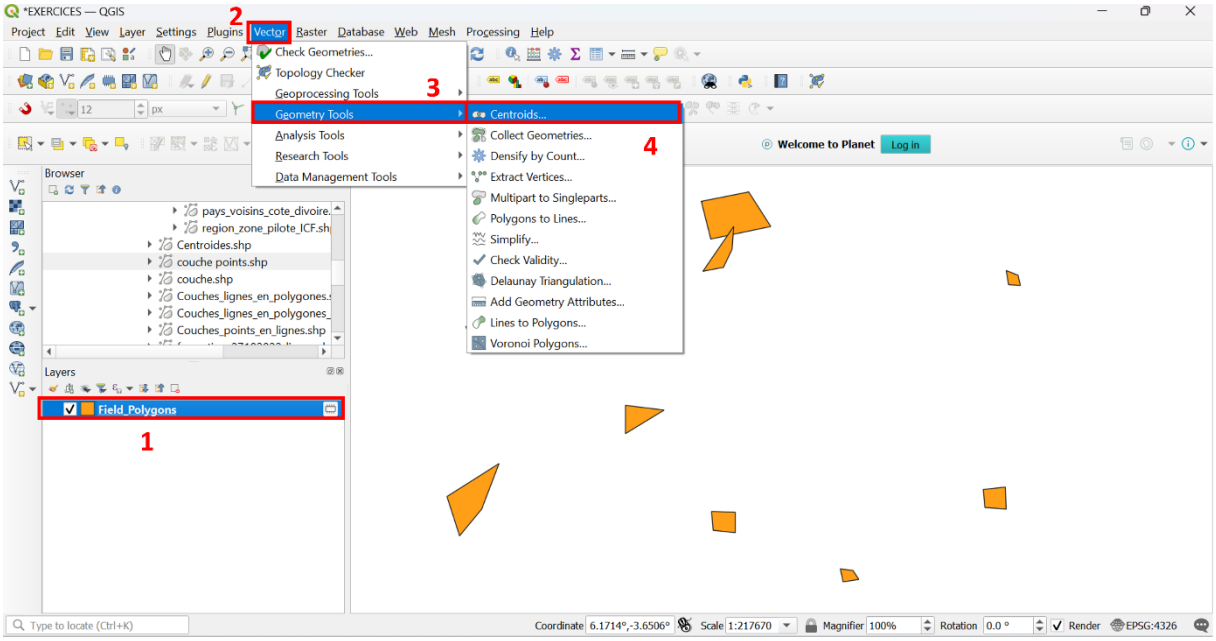
11.1. Purpose of the module

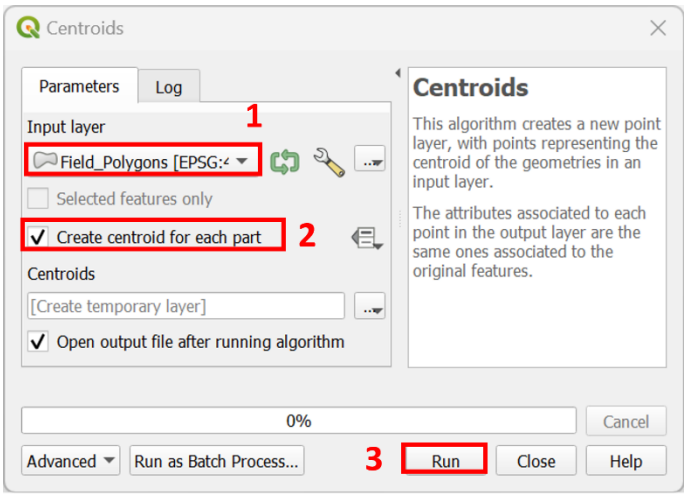
Just as you go out into the field to collect data and then come back to the office to process them, you can also prepare data at the office for further surveys, verification and analysis of objects or phenomena in the field, and even create visibility and reference points for the collection of other data in the field.

11.2. Creating centers of polygons

To locate polygons in the field with a GPS device, it is often easier to transform them back to points by calculating their geometrical centre. In this sub-section, we'll show you how to create them automatically with the QGIS software.

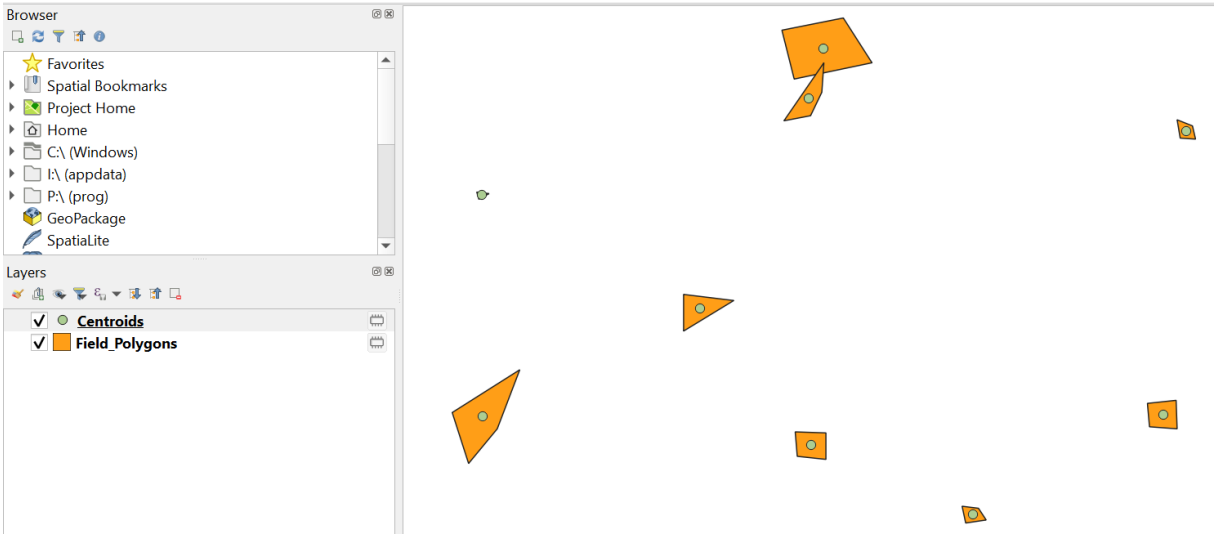
1. Mark the polygon layer in the *"Layers"* panel;
2. Select the *"Vector"* menu in the menu bar;
3. Unfold the *"Geometry Tools";*
4. Select *"Centroids".*





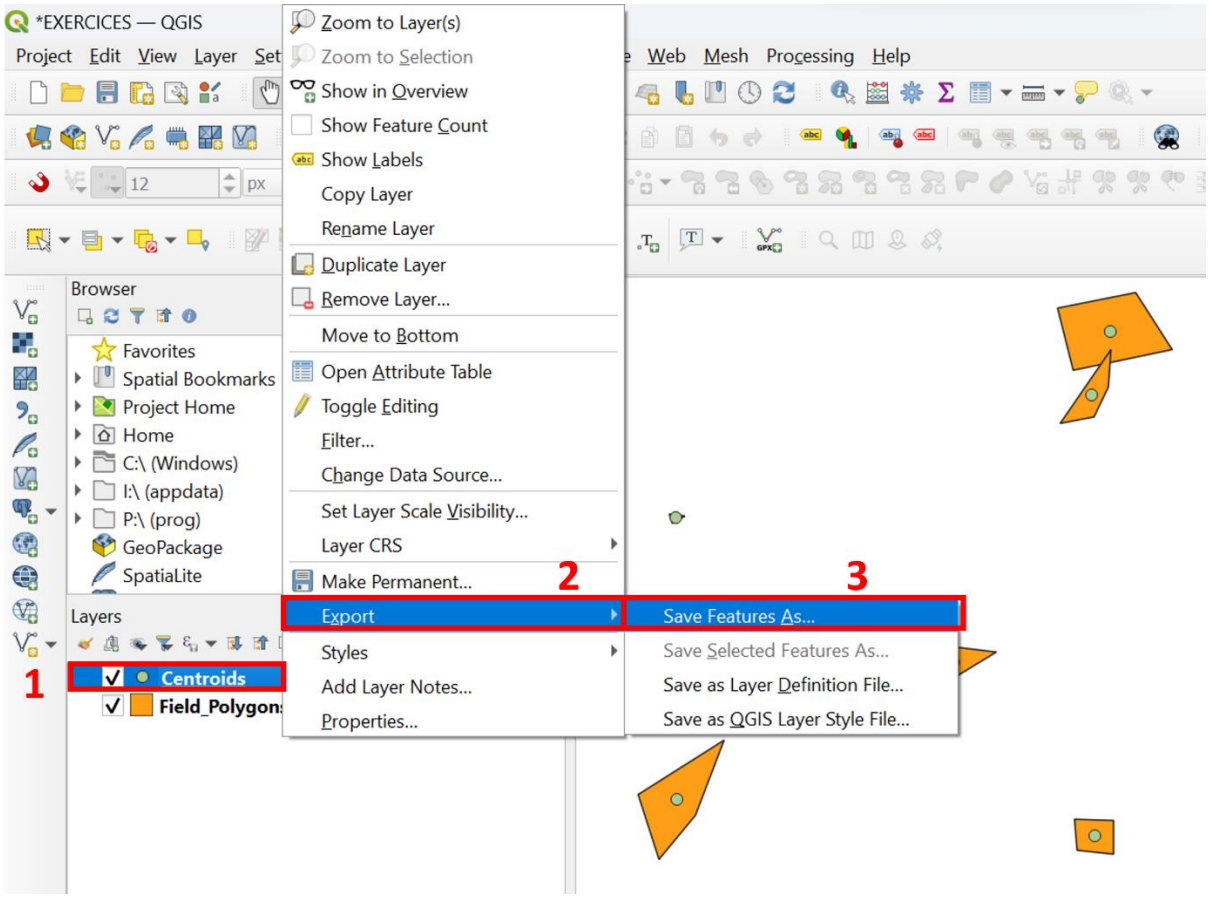
Within the dialogue box of the *"Centroids"* function select your polygon data layer as *"Input Layer"* (1). Tick the option *"Create centroid for each part"* (2). Finally execute the calculation via a click on *"Run"* (3).

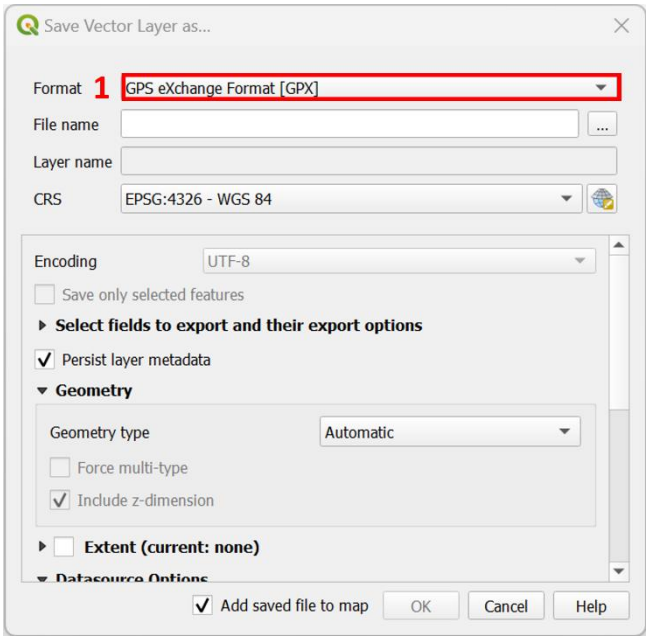
You can now see that every polygon is represented by a central point.



11.3. Export point data to GPX file

In order for your GPS device to read these or any other point data, you will have to transform the point layer to GPX format via the export function. Select the layer in the ***"Layers"*** panel and right-click on it (1). Select ***"Export"*** (2) and ***"Save Features As"*** (3).





In the opening dialogue box, select the *"GPSeXchange Format [GPX]"* (1) format, choose a file location and click *"OK"*.

11.4. Importing the GPX layer into the GPS receiver or smartphone

If you are working with a GPS device, follow these steps:

- Connect the GPS device to the computer;
- Navigate to your local folder containing the **GPX files**, copy them and paste them it into the **GPX** folder of your GPS device.

Alternatively, if you are working with a GPS enabled smart phone, there are several free Apps that can visualize GPX data, such as Organic Maps or MAPS.ME. In that case, follow these steps:

- Transfer the GPX files to your smartphone (either via plugging it to your desktop computer or any other transfer option) and save them at your preferred location on the phone.

Open the GPX files with whatever app you are using.

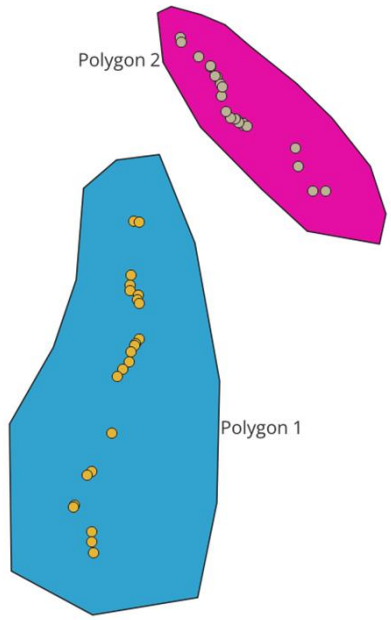
XII- MODULE 12: FINAL EXERCISE

12.1. Exercise 1

1. As part of this exercise, you will first create a QGIS project called ***"Exercise".***
2. From the ***"Exercise_Data"*** folder, import into QGIS the two GPX files named ***"Waypoints_11-NOV-21.gpx"*** and ***"Waypoints_15-NOV-21.gpx"*** respectively.
3. Convert these two files into SHP format and then export them to a folder called ***" SHP"*** inside the ***"Exercise_data"*** folder. The files should be named ***"Points_15-NOV-21_shp"*** and ***"Points_11-NOV-21_shp"*** respectively.
4. Merge the two files into a single file called ***"Points_NOV-21-merged_shp"***.

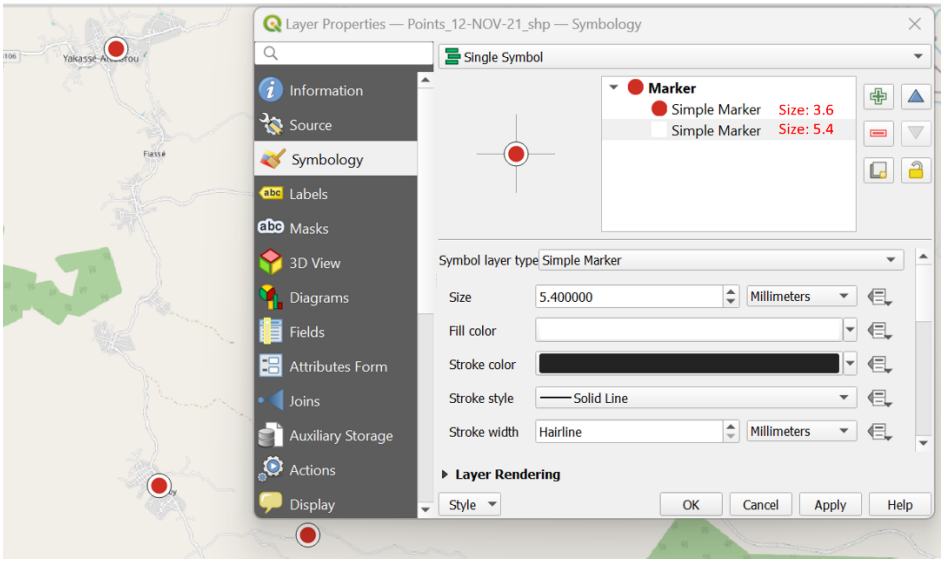
12.2. Exercise 2

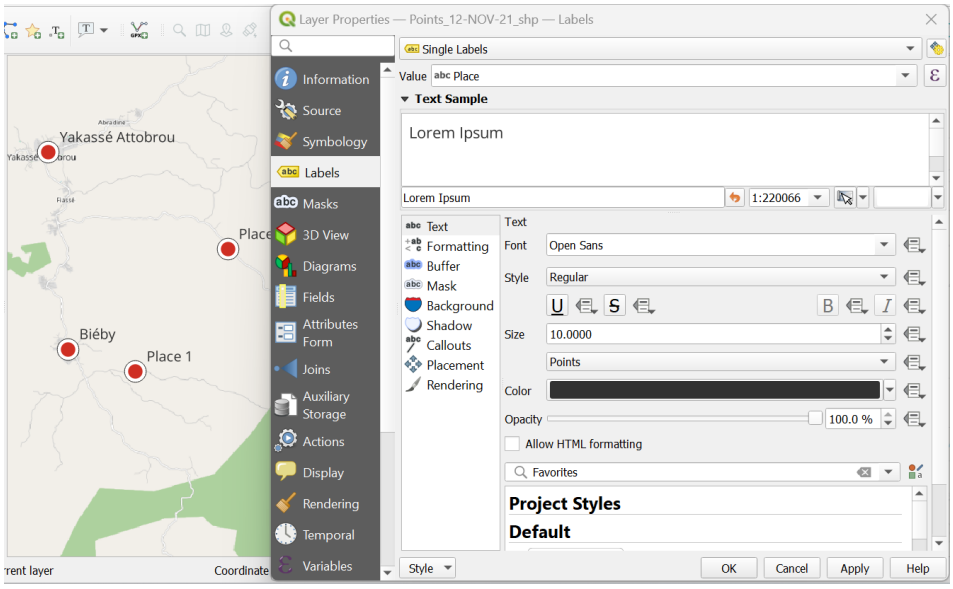
1. Edit the ***"Points_NOV-21-merged_shp"***, then **add 5 new points** that you will create manually and directly from your QGIS software. When editing, name them consecutively (New point 1, New point 2, New point 3, etc.).
2. Depending on the arrangement of the points, create a new polygonal shape file named ***"Polygon_NOV-21_shp"*** with a column ***"NAME"*** and then digitise two polygons around these points. Each polygon created should be named Polygon 1 and Polygon 2. Below is an example:



12.3. Exercise 3

1. For this exercise, the layer used is ***"Waypoints_12-NOV-21.gpx".*** Import the file into QGIS, transform it into an SHP layer, go to the attribute table, add a ***"Place"*** field column and name the two points ***"Place 1"*** and ***"Place 2"*** respectively.
2. Then call up the ***"OpenStreetMap"*** background map and digitise two more points. These points must be at the places of ***Yakassé Attobrou*** and ***Biéby*** marked on the OpenStreetMap base map. In the column for the ***"Place"*** field, name each point after the town marked on the OpenStreetMap base map.
3. Now, create the suggested symbology and labelling (see figure below).
4. At the end of this exercise, you will create the layout (with all the elements that should be included on a map) and export the map as a PNG image and then as a PDF.





12.4. Exercise 4: Set a CRS

In the *"CRS_Error"* folder, load the *"18-NOV-21_parcelles"* layer into your QGIS project. Normally this data should be located within the country of Honduras but is seems to be mislocated. The wrong CRS has been linked to it. But since you know that the data was originally collected via GPS, correct the CRS to EPSG:4326 - WGS84. Save the file as *"18-NOV-21_parcelles_WGS84".*

12.5. Exercise 5: In search of a point

This exercise asks you to find an object located at a precise point in your area. Take any of your files or create a file that contains polygon field data from your region:

1. Create centroids of your polygons.
2. Save the point data as a GPX file to a corresponding *"GPX"* folder.
3. Transfer this data into a GPS/smartphone and go to one of the marked locations using your GPS device.

12.6. Exercise 6: Spatial analysis and sustainable resource management

You are the technical supervisor of a local cooperative, and you have digitized your fields in the recent past. Within the *"parcels.shp"* shapefile contained in the *"Spatial_Analysis"* folder you have some exemplary data of this. You additionally have a *"forests.shp"* layer within the same folder. It is now your task to check whether your field polygons are located within forests or not:

1. How would you approach this task?
2. Save the parcels that intersect with forests as a file *"parcels_in_forests.shp"* within the *"Spatial_Analysis"* folder.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