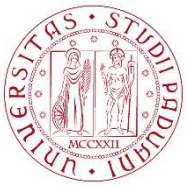

UNIVERSITÀ DEGLI STUDI DI PADOVA

Extra handout on Coordinate Reference Systems for the course "GIS for Agro-Environmental Sciences"

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Coordinate Reference Systems for GIS

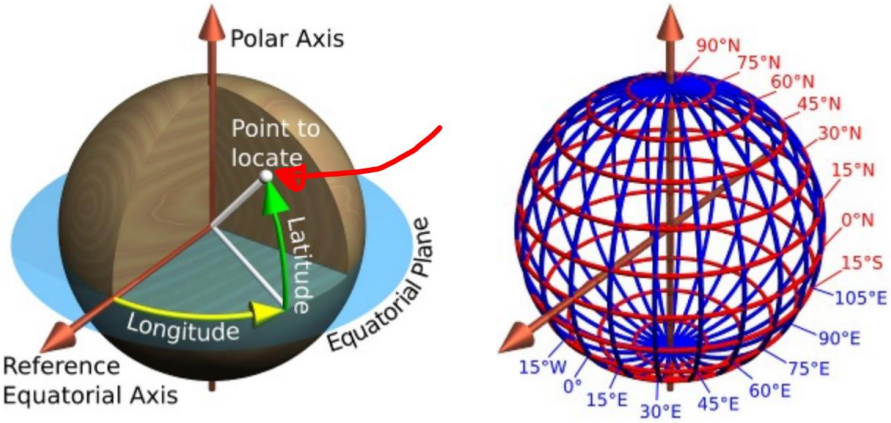
Intro: **Coordinate Reference Systems (CRS)** are conventional 2D or 3D spaces that are used to define coordinates in a conventional space. Space is defined by a coordinate reference frame, i.e. 2 or 3 axes with an origin and orientation (Cartesian coordinate system – see https://en.wikipedia.org/wiki/Cartesian_coordinate_system). This allows peers to share information on a conventional space – e.g. "hello Bob, I left your car parked at 11°57'23" 45°20'39"[1].

Some CRSs use angles and are considered global, and are called "Geographic reference systems", whereas others are limited to certain areas and are called "Cartographic reference systems". *Carto* means "paper" and implies that they are flat surfaces, on the contrary of geographic systems where angles define a point on a flattened sphere called "ellipsoid" which is a mathematical representation of the earth (not exact but "close enough")

[1] Exercise: open QGIS and load Google Satellite layer using the QuickMapServices Plugin (check the last part of the handout on "How to access geodata" in Moodle). Set-up your project to Geographic CRS (EPSG:4326) – answer the following question: what is the object and color that you see at coordinates 11.9567527,45.3442216?? Click Here for Answer

Geographic reference systems

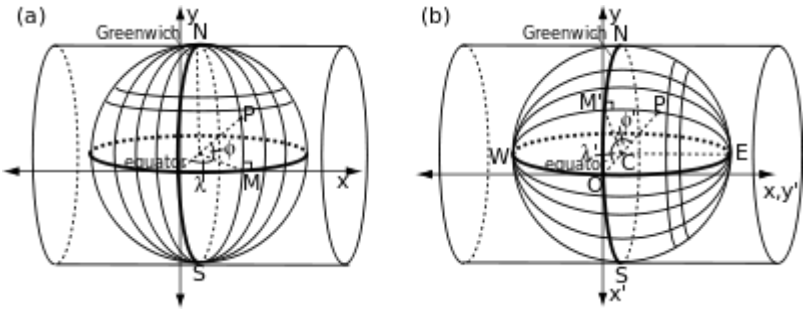
Two angles are used to define a point on the surface of the ellipsoid, LATITUDE and LONGITUDE. There are many systems to define angles (radians, centesimal, sexagesimal, (sexa)decimal). Latitude and longitude are usually expressed in sexadecimal e.g. 12.03214° longitudine & 45.32423° latitude or DMS (degrees minutes seconds) e.g. 12°05’21.54” longitude, 45°20’10.5” latitude.



So the conventional reference frame has origin at the earth center, one axis is the rotational center, another axis passes Greenwich coincident with the equator, and the other is consequently orthogonale (90°).

Cartographic reference systems (projected)

Cartography is the discipline that tackles the challenge of representing a complex 3D reality on a plane (*Carta* mean “paper” in latin). This is done by projecting the objects that want to be represented on the flat surface. Deformation will always happen when doing that, therefore the challenge was to create methods to get the largest area represented with the least deformation. The most common for many is the Universal Trasversal Mercator – UTM which like the image below, uses a cylinder. The tangent to the cylinder will be a MERIDIAN (the black vertical line in the figure below) which is called the reference meridian. Because of deformations, the area that can be represented is limited to +/- 3° longitude from the reference meridian - so a total width of 6°. For the whole world there are therefore 60 different zones. Italy is covered by zone 32 and zone 33.



For another source of information, check the link below!

https://docs.qgis.org/testing/en/docs/gentle_gis_introduction/coordinate_reference_systems.html

It gets more complicated

As you have seen, geographic and cartographic reference systems are referred to an Ellipsoid that represents the Earth. The Ellipsoid is defined by two semi-axes, minor and major, and in history, these have been measured several times, coming up with slightly different values. Therefore, there are different ellipsoids

that can be used, and different orientation and positioning methods: these further details define a DATUM. Most CRSs now use the WGS84 DATUM (WGS ellipsoid which is "geocentric", i.e. its origin is at the earth's center of mass) because it was defined in 1984 by GPS satellites. Take-home-message: different DATUMS bring difference in coordinate values, therefore check your data.

How should I deal with CRSs?

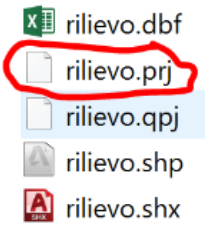
There are very many CRSs out there, so to create an easier look-up method, the EPSG consortium created numeric codes for referring to CRSs. The most common is the Geographic CRS which uses the WGS84 DATUM, which has a code of **4326**. For other codes you can reference https://epsg.io/ . For this course we will use different CRS as we will work in areas in Italy, in the USA and in Madagascar.

How do I know which CRS my data are in?

Let's imagine that you walk around with a GNSS (GPS) receiver and collect data about pathogen presence in a tobacco field – you will collect latitude and longitude. Therefore, your data will be in a geographic coordinate system. You know that, so you will assign the EPSG:4326 to your layer in your GIS software. But what happens if you get third-party data? Don't panic….

There are different ways that your data can carry info on CRS – here is a list of scenarios from most lucky to the least:

1. **integrated** in the file – you do not see it, but the file has that information embedded in the binary code inside the file. For example, GeoTIFF raster (.tif files) often have this information embedded. You just drag and drop your file in QGIS, and everything will happen "automagically".
2. In an **accessory file**: there might be a separate file containing the information. For example the shapefile format has CRS information in a file with **.PRJ extension** – if this file is available, you have CRS information, otherwise you are out of luck. Again if this file is present, everything will happen "automagically".



Sometimes raster files can have an accessory file with CRS information, usually their extension follows the convention of having the first and last letter of the extension, and a "w" as third letter. E.g. .TIF files will have .TFW, .JPG files will have .JGW etc…

3. "**metadata**" files, simple text files that contain information on the CRS, but are NOT read automatically by QGIS (e.g. "README.txt"). Metadata can contain any information useful for the user, such as:
    a. Creation date
    b. Author of the data
    c. CRS of the data

So if you have a metadata file, you KNOW the CRS, but you have to assign it through the properties panel of the layer in QGIS (right click on the imported layer and go to properties) see section Setup CRS of the LAYERS

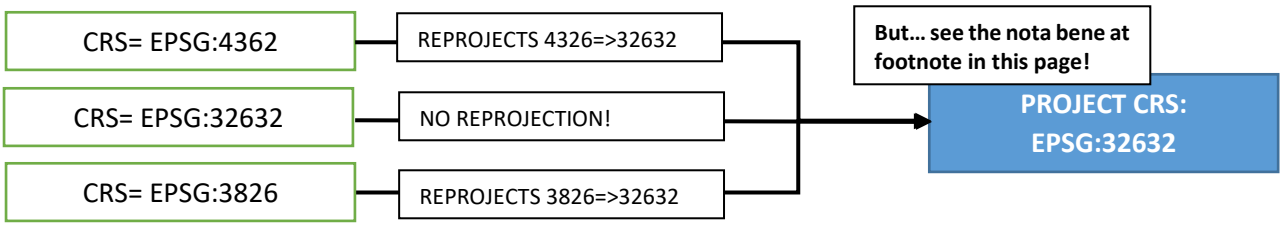
4. **NO info** – you either contact the data provider, or try loading it in QGIS and adding a base map (e.g. Google Maps) to see which CRS locates it correctly over the Google imagery. See next section on how to change CRS to layers.

Use CRS in QGIS

QGIS manages data in different CRS without problems, but it must be ensured that each layer has assigned the correct CRS of its data!!

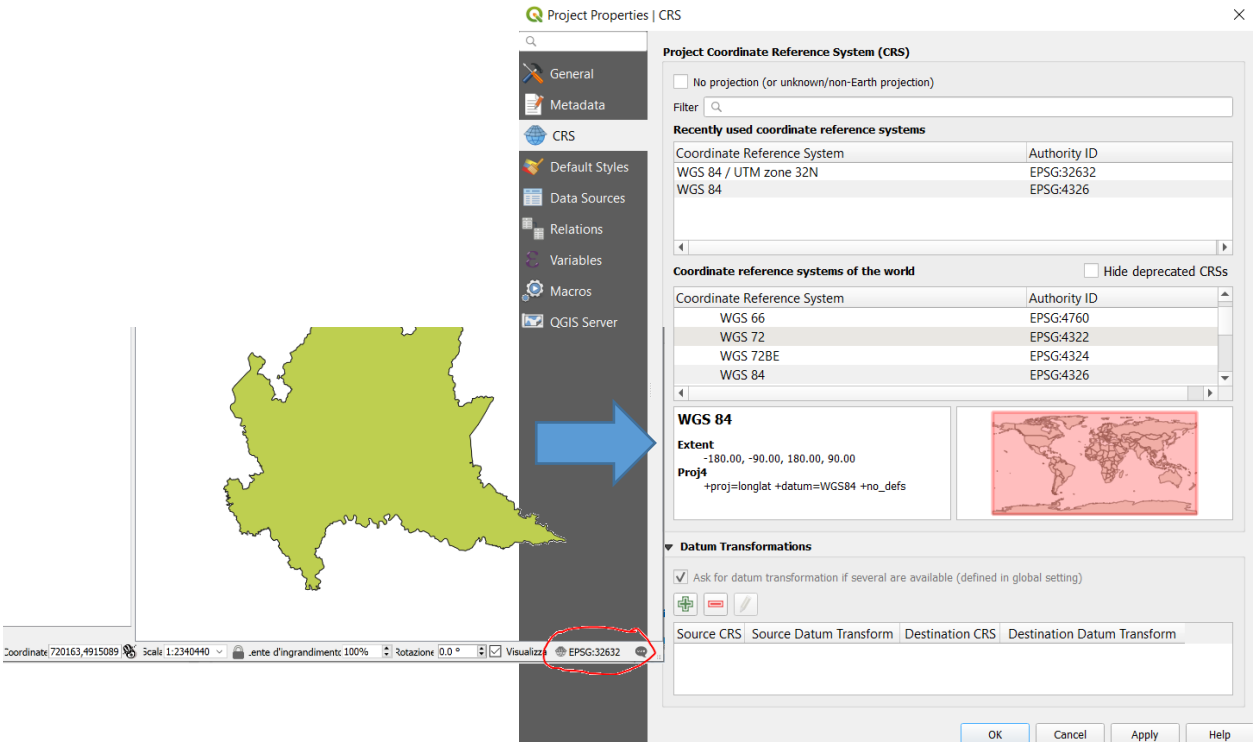
Setup CRS of the PROJECT

When you load the FIRST layer in the QGIS project, QGIS automatically sets up the CRS of the project to whatever is the CRS of this first layer[2]. Other data layers that you load, if their CRS are different, will be reprojected to the project's CRS. So, you will see your data placed correctly in the world[3].



The coordinates of your mouse pointer are visible at the bottom bar.

You can modify the project CRS by clicking the bottom right button. The panel shows-up where you can choose any CRS you want[4].



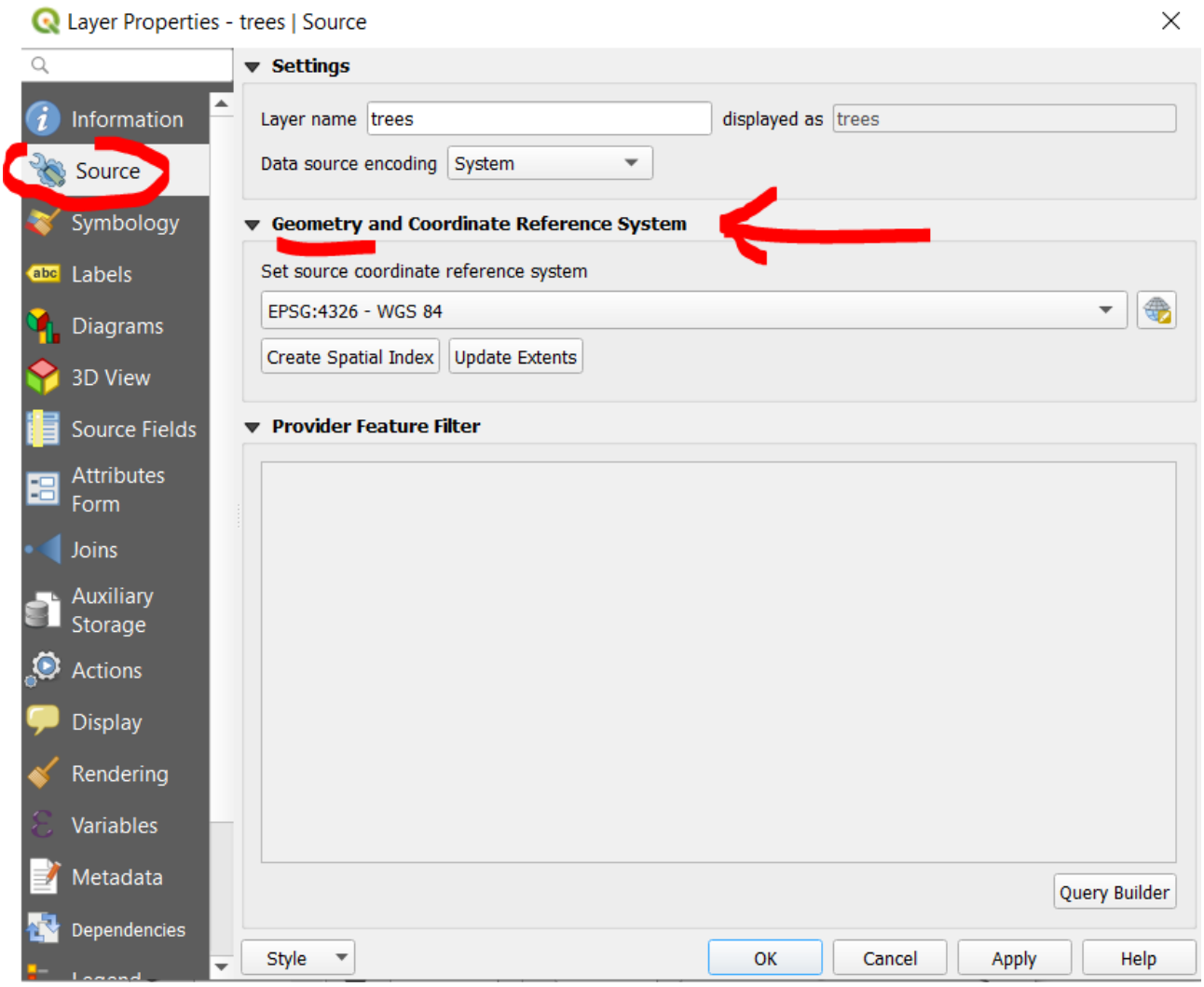
[2] This can be changed in the project properties – see section Project options related to CRS

[3] ***Nota Bene**: the reprojection is **virtual** in the sense that the data coordinates will not be changed in the file, but only on the screen. This means that some operations in GIS **will not work** if they use two layers in different CRSs. For example, if you want to apply a raster difference – for example subtract a temperature raster from 1990 from a temperature raster from 2019 – and one raster is in CRS=EPSG:4326 and one is CRS=EPSG:32632, it will not work, because the original data are different. Therefore, to make things work it is necessary to save one of the layers in the same CRS as the other.*

[4] Exercise: change the project CRS to a projected system that is far from your study area, for example if you work in Italy and are using data in EPSG:32632, choose EPSG:32649 which is a completely different zone – you will see distortions due to the zone being far from your area.

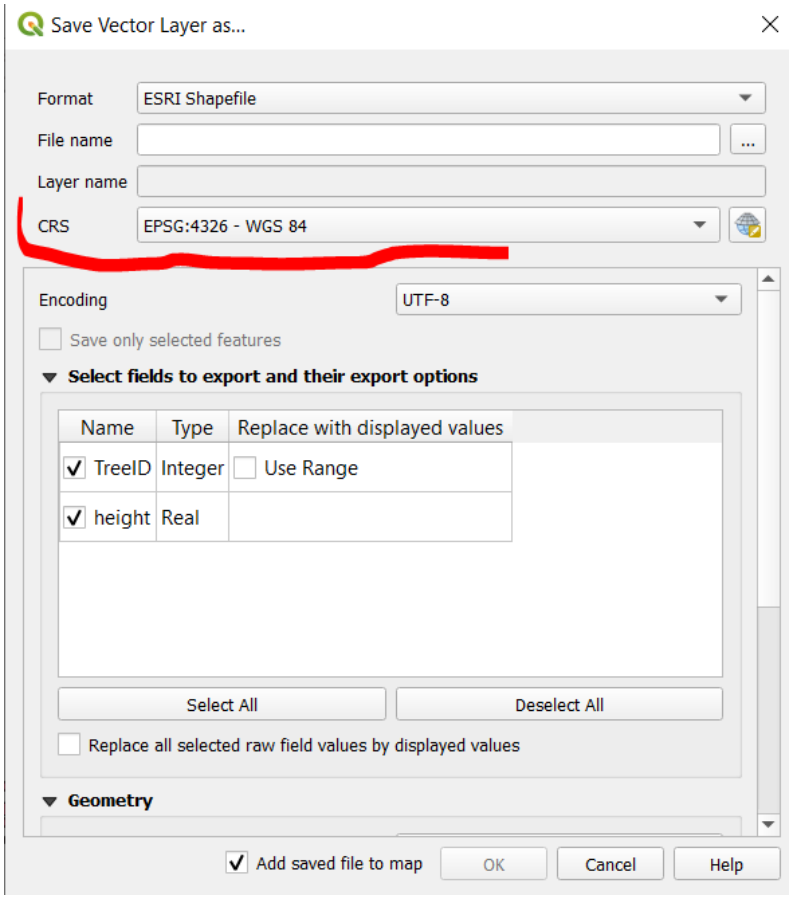
Setup CRS of the LAYERS

Each layer must have the correct CRS assigned to its properties. If it is not automatically defined when loading it in QGIS (see section How do I know which CRS my data are in?) OR you want to change it because you think it is not correct, you have to right click on the layer, and select PROPERTIES – choose the properties tab. Go the the "source" tab and choose the correct CRS from the drop-down list of recent CRSs, OR from the small button on the right of the drop-down list.



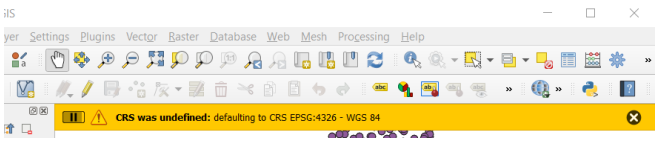
Change CRS of a dataset

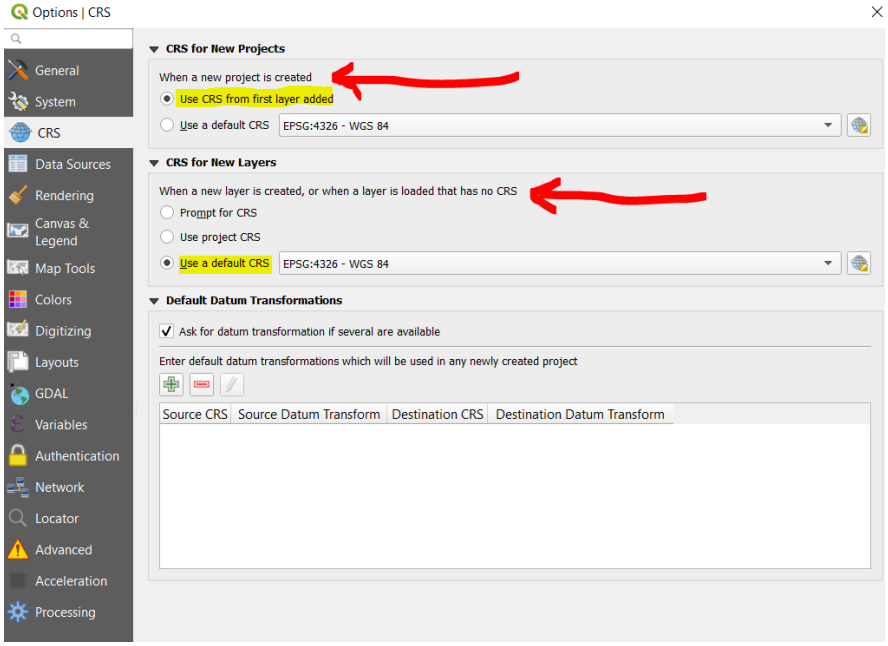
To change CRS of a dataset, you must load it to QGIS, assign its current CRS correctly to the layer, and save the layer in a new file, specifying the CRS. You do so by right-clicking the layer, and choosing “Export” => ”Save features as” and changing the CRS value in the panel (see figure below)



Project options related to CRS

If you go to the menu bar on top of QGIS and select “Settings”➔”Options”➔”CRS tab” you will see what happens in case you open a project in QGIS, and when you load layers. Default values are shown in image below, but these can be changed to suit your needs. Remember that loading layers with unknown CRSs will trigger a warning message that appears with an orange band on top of the QGIS view – and disappears after a few seconds.





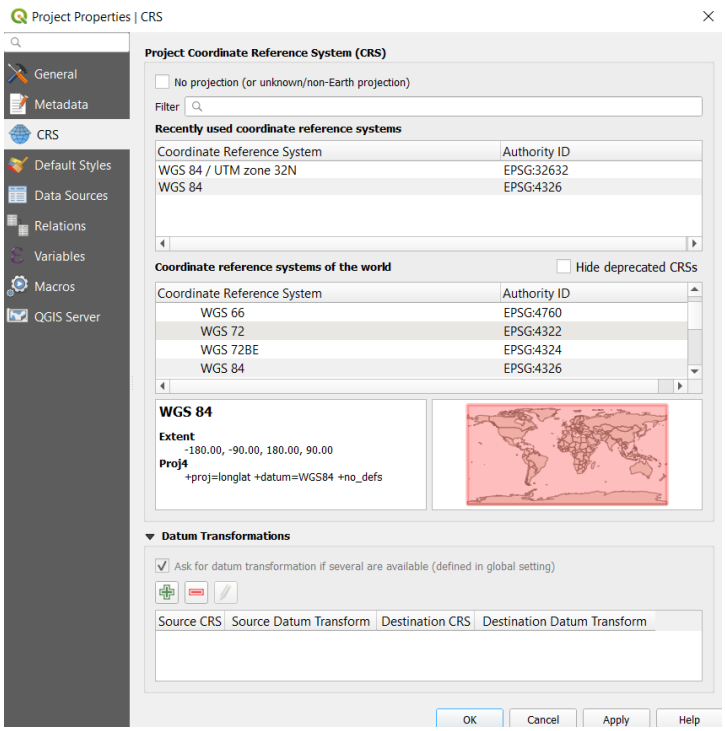
Exercise to understand CRS in layers

Get the mountain-goats dataset from Moodle

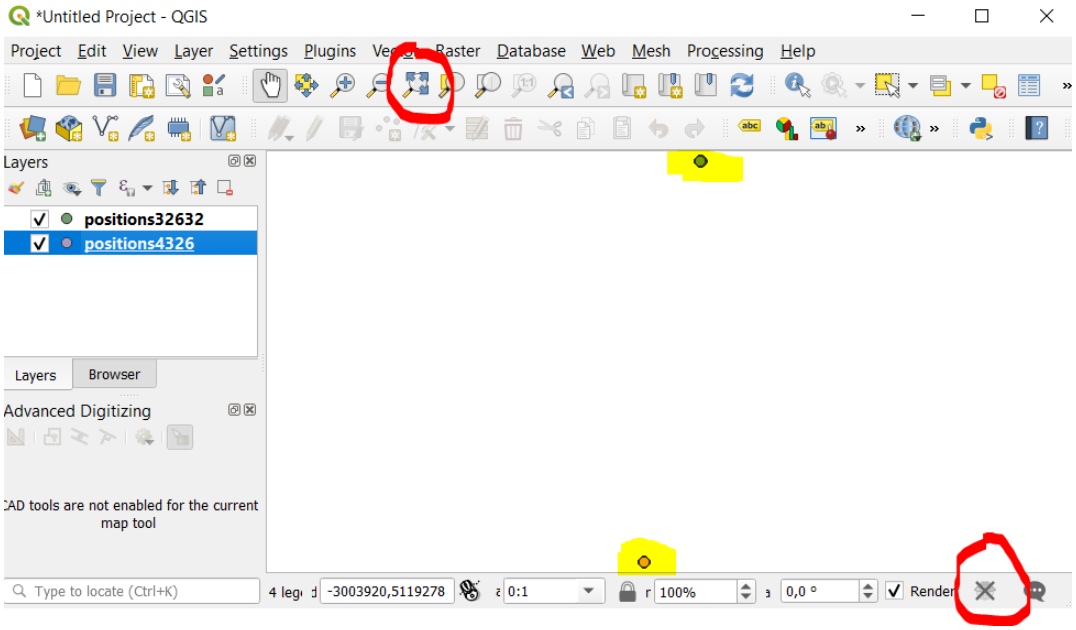
(https://elearning.unipd.it/scuolaamv/mod/resource/view.php?id=85226)

You will find two coordinate systems in the table "posizioni.csv" – one is EPSG:4326 in the columns "longitude" and "latitude", another is in EPSG:32632 in the columns "xcoord" and "ycoord". Load them in QGIS twice, using the two CRSs columns , (if you do not remember how, follow the *Importing Spreadsheets or CSV files (QGIS3)* tutorial online). You should see the two point sets overlap perfectly with each other.

Go to the menu bar in QGIS and select "Project"➔"Properties"➔"CRS tab" and in the panel that pops-up SELECT the first option "No projection (or unknown/non-earth projection)" – which becomes checked. This will disable the capability of reprojecting the layers that have a different CRS from the project – you will see at bottom right of your QGIS window that the CRS information of the project gets crossed out (see image below).



If you move your data (screen must refresh) you will see that the two point sets do not overlap anymore! If you zoom to all the area (see highlighted icon in image below), you will see that your points are plotted in completely different areas. This is because QGIS reads the coordinates WITHOUT doing any reprojection, so it keeps the values and puts them on screen as they are.



Answer: a red car (as of October 2019)