

Geodata Collection and Analysis for Empowering Women in Turkana County

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Science for [life]



Co-funded by
the European Union

Day 1: Introduction

Objectives, definitions, examples

Science for [life]

Introduction

■ Dr. Thomas Bauer

Senior Lecturer at BOKU University (since 2003)

Institute of Geomatics



Academical background

- Master in Geography/Cartography (University of Vienna)
- PhD in Remote Sensing (Technical University of Vienna)

Teaching courses (bachelor/master level) in:

- Geographic Information Systems
- Remote Sensing



www.boku.ac.at

Acknowledgement

This training is part of the Africa-UniNet Project 147 – „Towards Positioning Lifelong Learning For Women Empowerment In Turkana County” financed by the Austrian Federal Ministry of Women's Affairs, Science and Research (BMFWF) and implemented by OeAD.

<https://africa-uninet.at/en/projects/call4/p147-kenya>

africauninet

 OeAD

Objectives of the training

- **How can Geographic Information Systems (GIS) help for empowering women in Turkana?**
 1. Collect (geo)data representing the driving factors for inequalities or problems!
 2. Analyse these data and their spatial relationships!
 3. Present data to local authorities to make problems visible!

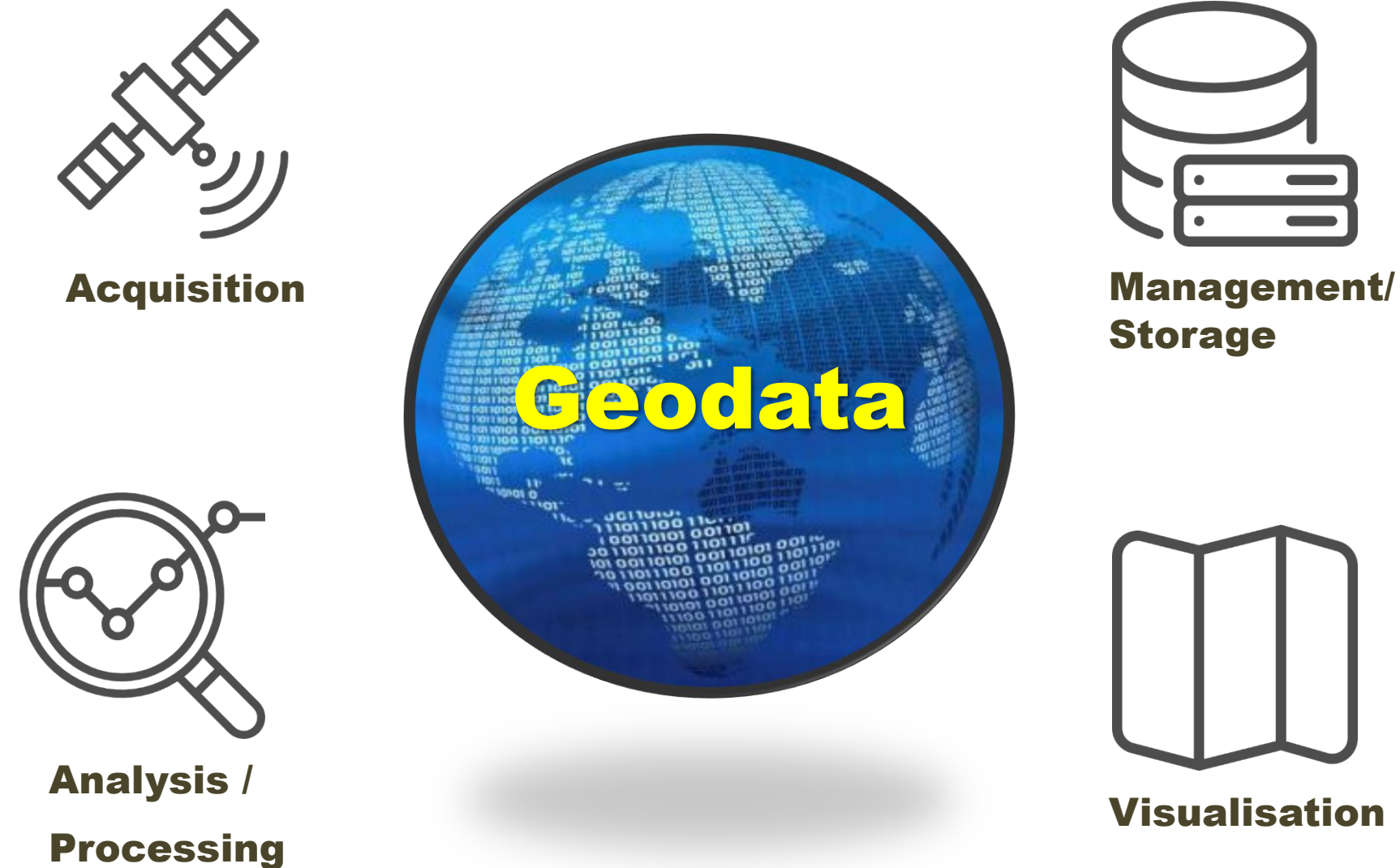
Schedule

	September 25, 2025	September 26, 2025
9:00 – 10:15	Introduction to GIS	Data collection in the field
10:30 – 12:00	Visualisation of geodata	Editing data
<i>Lunch break</i>		
13:00 – 14:45	Data management and coordinate systems	Data analysis
15:00 – 17:00	Data acquisition	Map production

Geographic Information Systems (GIS)

- **What is a GIS?**

A GIS is a system for collecting, managing, and analyzing geographic data.



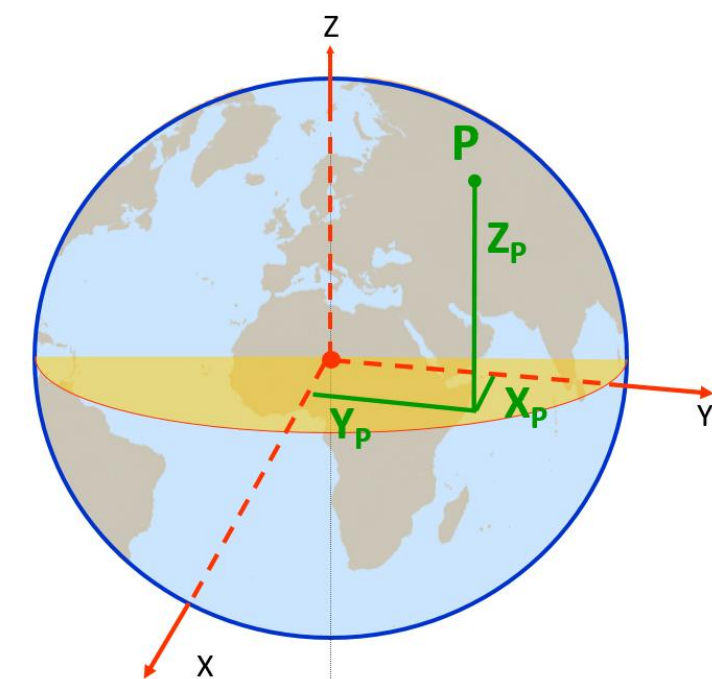
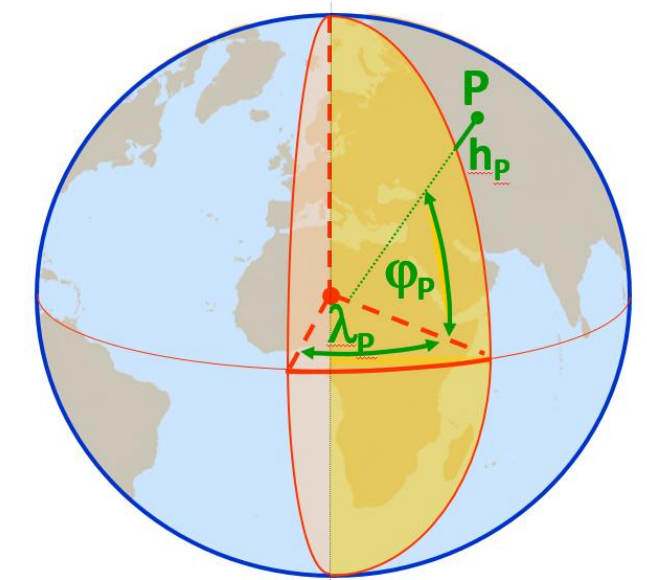
Geodata

- **Geodata (geographic data) is data with a spatial reference**

→ Spatial data

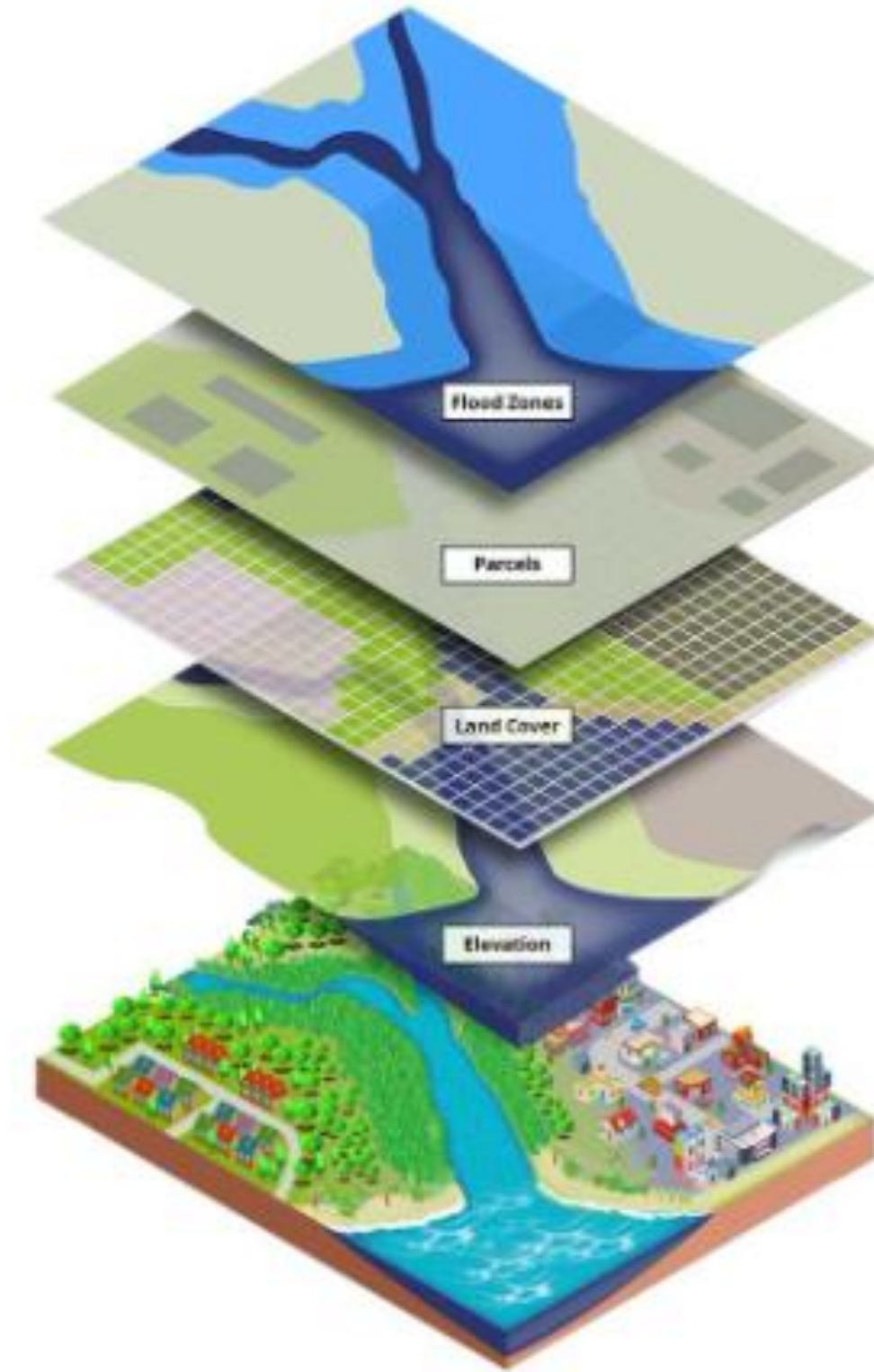
→ Refer to a position in geographical space ("georeferenced")

→ Locate objects, phenomena, ... on a map. "What is where?"



Geographic Information Systems (GIS)

- **GIS will answer questions, such as:**
 - What is at a specific location?
→ identifying what exists at a particular place
 - Where does it exist?
→ involves finding locations that meet specific criteria
 - What has changed since...?
→ how things have changed over time in a given area
 - What spatial patterns exist?
→ relationships and anomalies in data
 - What if...?
→ used for forecasting and planning



<https://gisgeography.com/what-is-gis/>

GIS is a tool for answering questions that involve location and spatial relationships.

GIS: The Science of Where

- **Data Integration:**

GIS connects descriptive data (like population or environmental information) with its location on Earth, providing a unique spatial perspective.

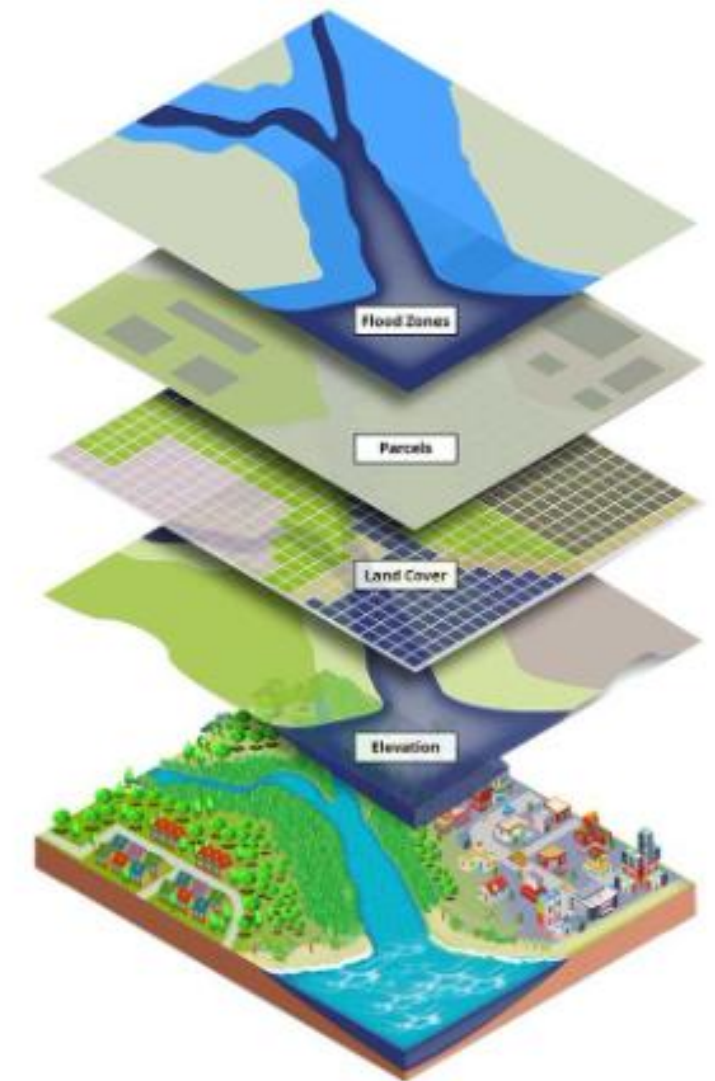
- **Pattern and Relationship Discovery:**

By layering information and visualizing it on maps, GIS helps users identify trends and correlations that might otherwise be hidden in raw data.

- **Problem-Solving:**

Organizations and scientists use GIS to address complex issues, such as:

- **Urban Planning:** Determining optimal locations for new infrastructure and development.
- **Environmental Studies:** Mapping disease outbreaks, wildlife movement, or changes in glaciers.
- **Social Sciences:** Analyzing social justice issues or the dynamics of global conflicts.
- **Conservation:** Identifying areas for sustainable land management and protection.



<https://gisgeography.com/what-is-gis/>



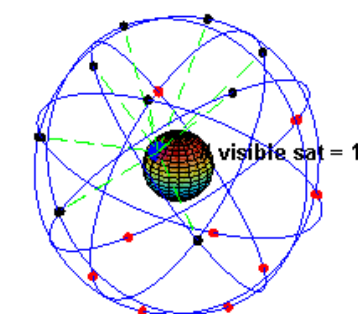
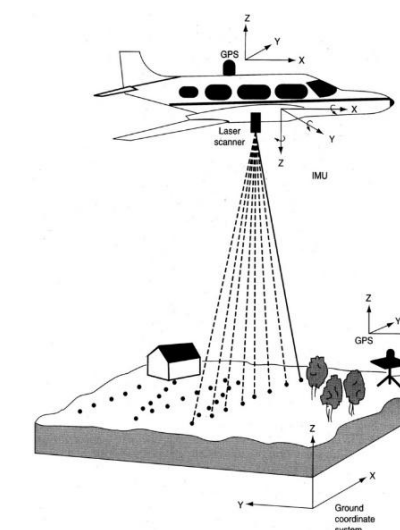
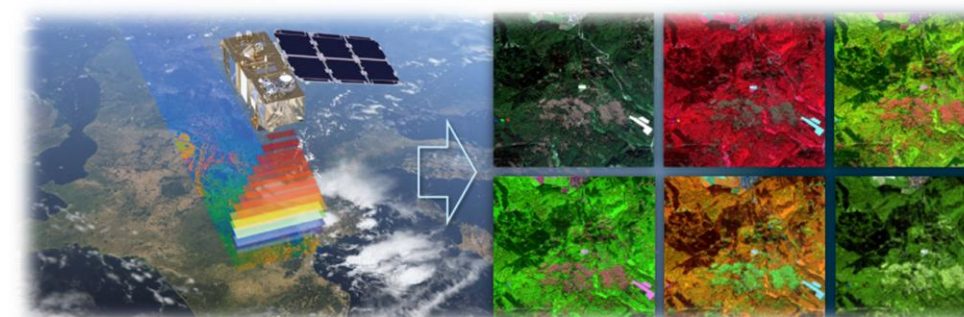
Acquisition

Data acquisition

- GIS data acquisition is the process of gathering and inputting spatial and non-spatial geographic data into a GIS to support decision-making, research, and analysis.

- **Primary Data Acquisition:**

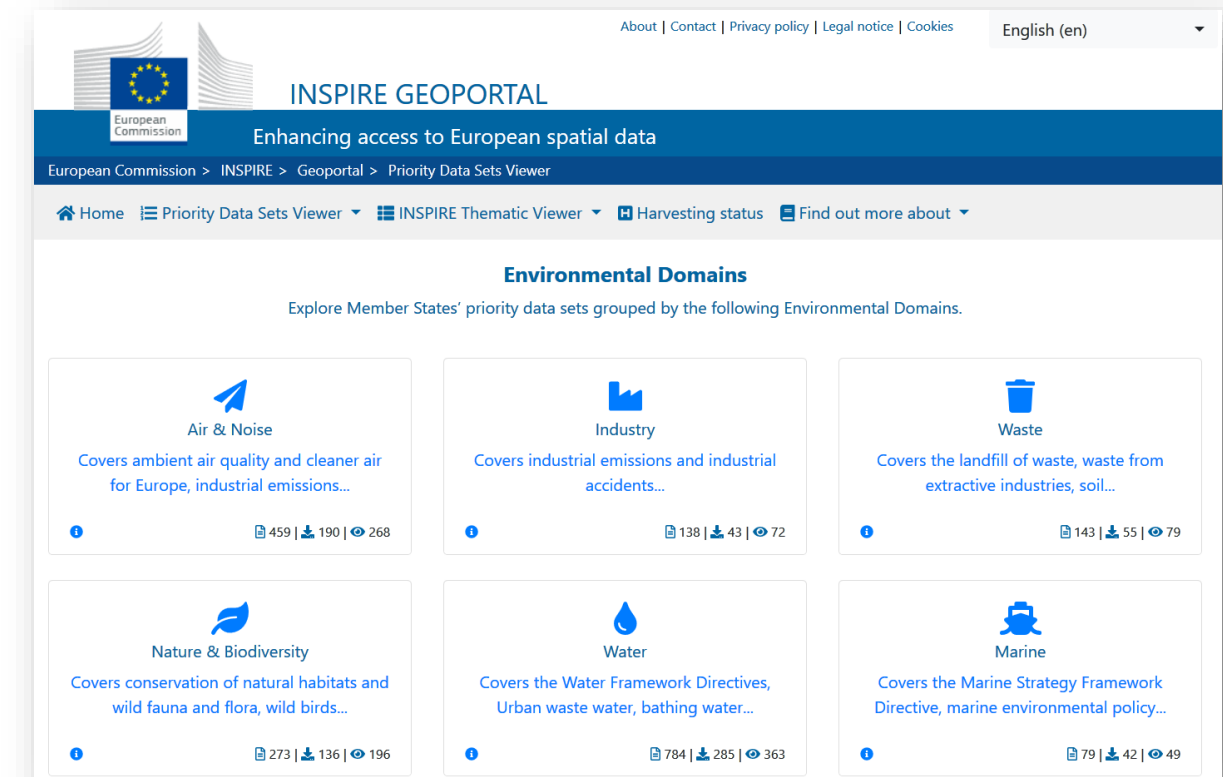
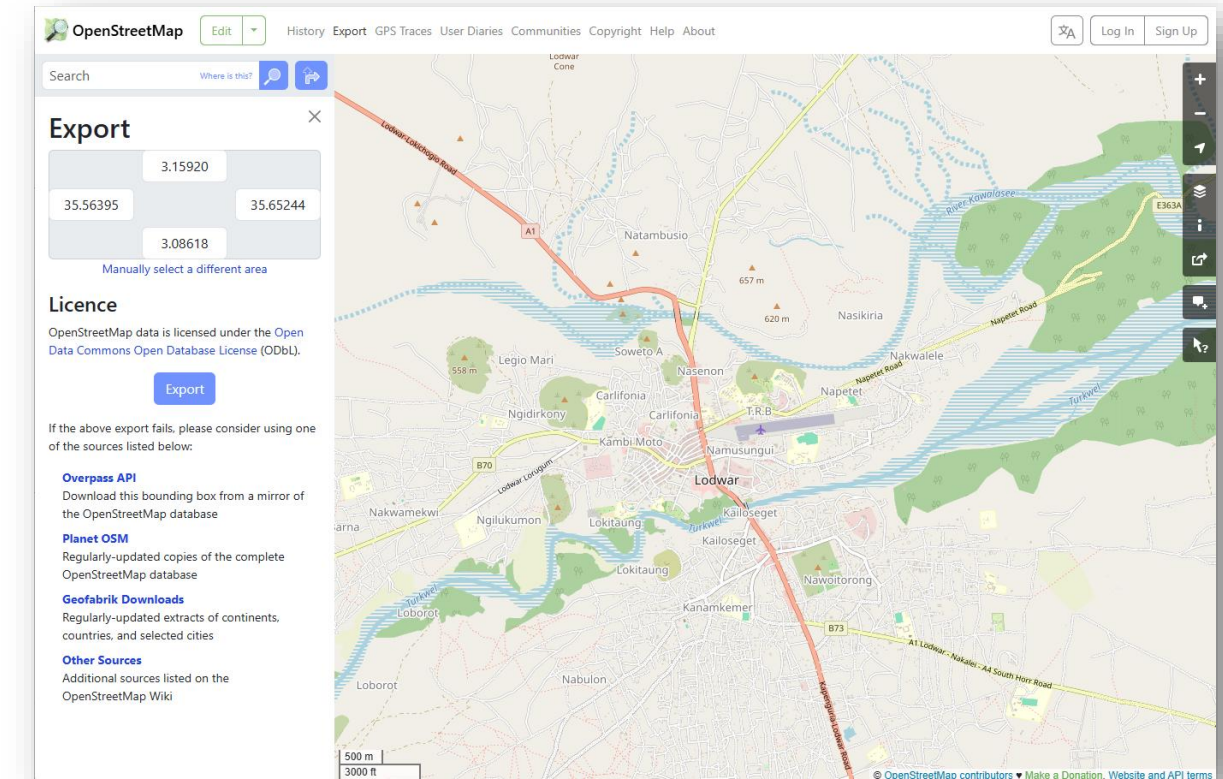
- Involves collecting new, raw data directly from the source.
- Remote Sensing: Using satellite imagery and aerial photography to capture spatial data without physical contact.
- Field Surveys: Employing tools like GPS to collect precise location data for specific sites.
- Drones/UAVs: Utilizing Unmanned Aerial Vehicles to capture detailed aerial data.
- Wireless Sensor Networks: Collecting real-time data from a network of sensors deployed in the field.



Data acquisition

• Secondary Data Acquisition:

- Involves acquiring data that has already been created or collected by others.
- Digitizing/Scanning: Converting analog data from physical maps into a digital format suitable for a GIS.
- Purchasing Data: Acquiring pre-processed spatial datasets from commercial providers.
- Data Exchange: Sharing and collaborating with other organizations or government agencies to obtain data.
- Using APIs (Application Programming Interfaces): Allowing different software applications to communicate and exchange data directly, often for web-based data.

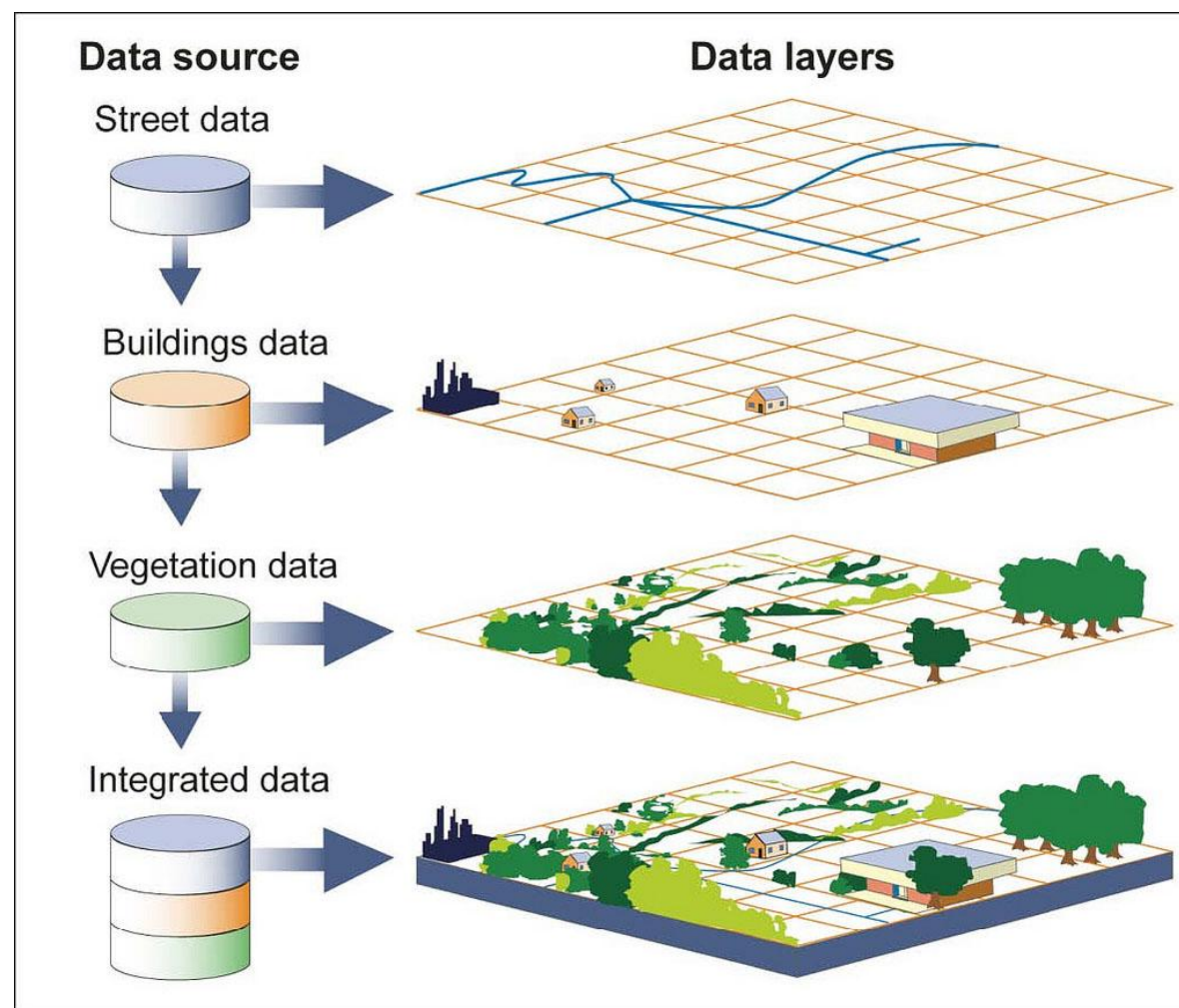




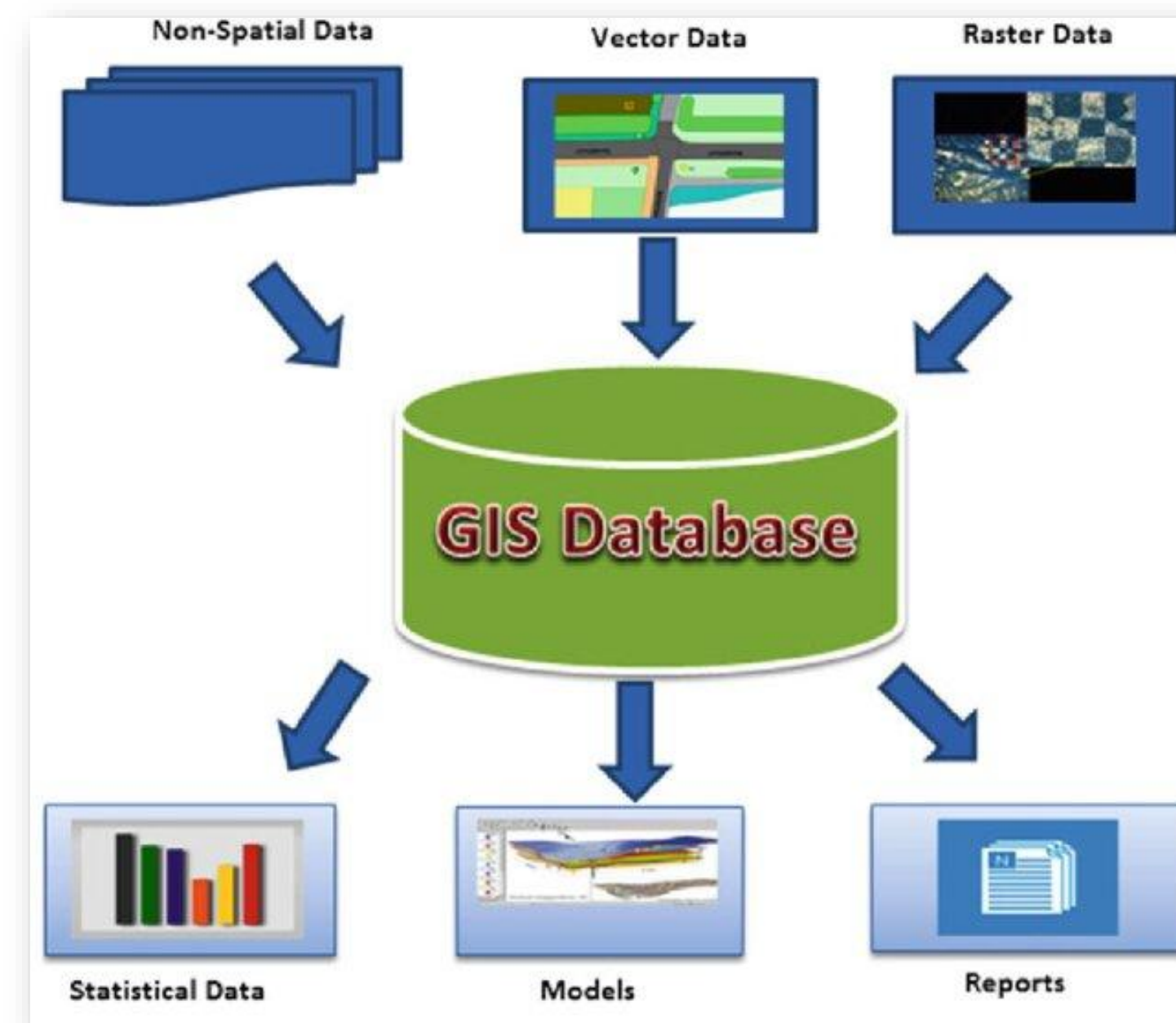
**Management/
Storage**

Data management

- Data management is the practice of collecting, storing, and using data securely and efficiently, helping organizations make informed decisions.
- **Several special data formats**
- **Database systems**

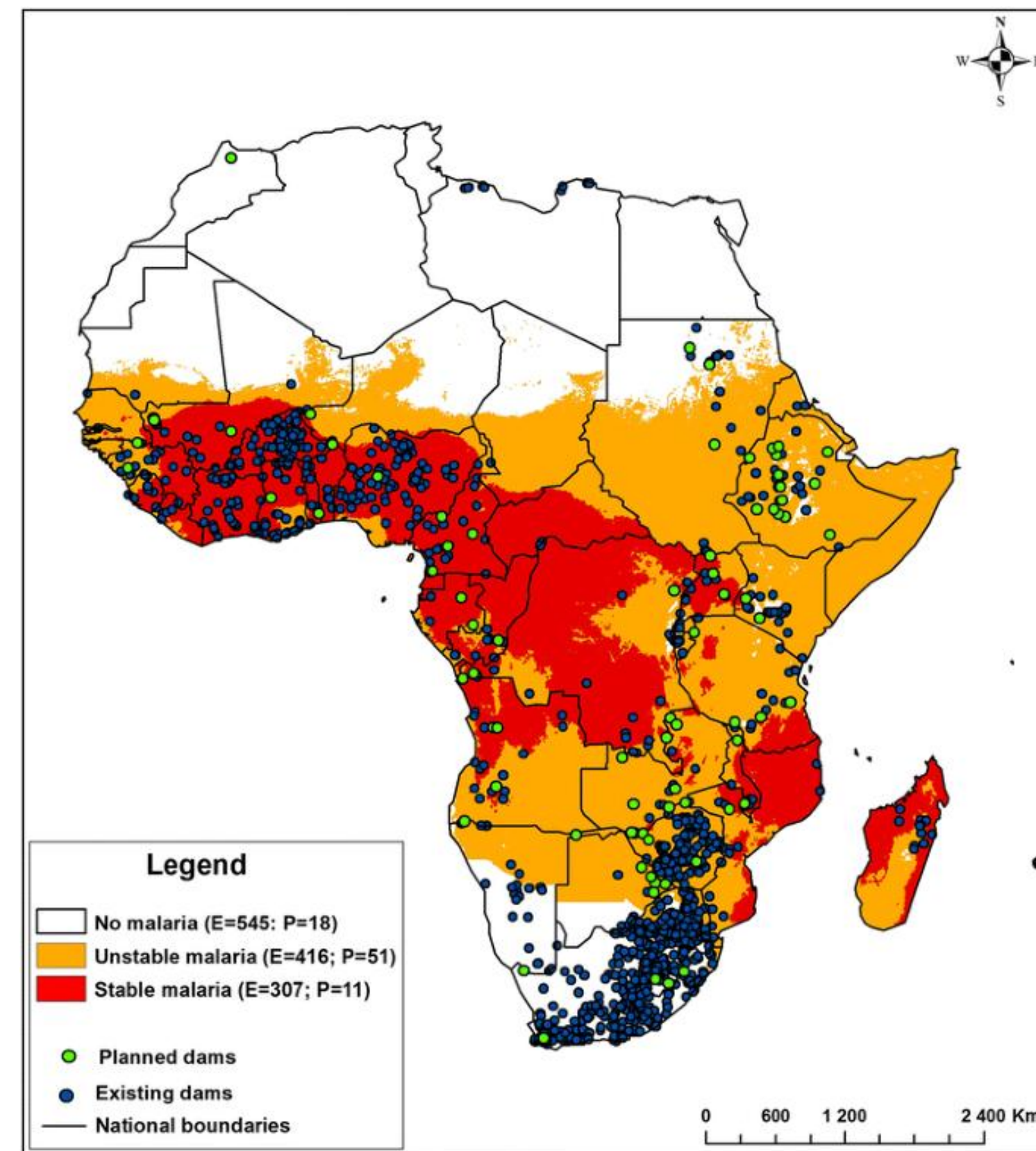
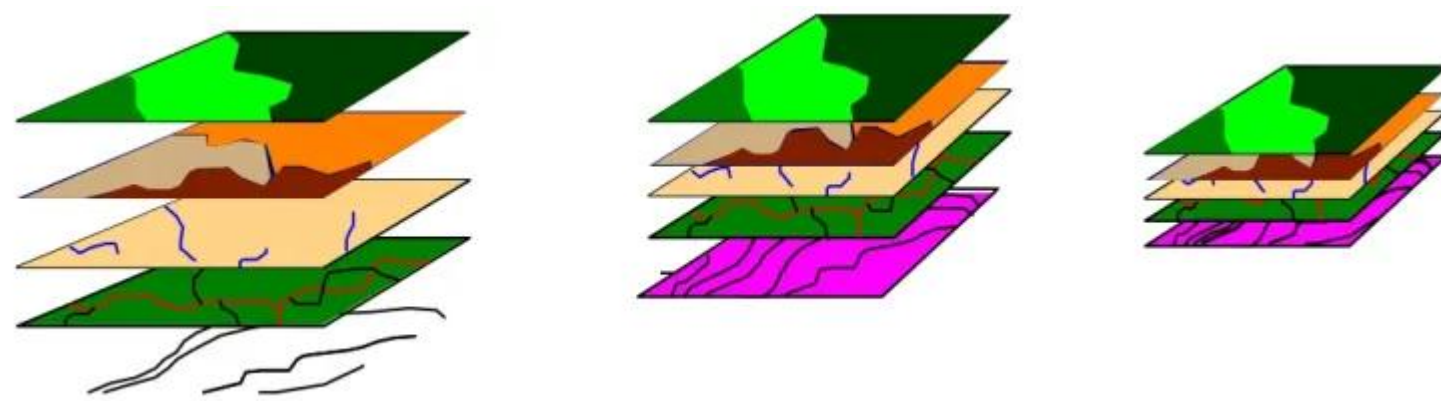


Source: GAO.



Data analysis

- **Spatial distribution:** analysis of how features, phenomena, or data are arranged across a geographic area, helping to identify patterns and relationships.
- **Overlay analysis:** involves combining multiple geospatial data layers to create a composite map that shows the spatial relationships between different features.

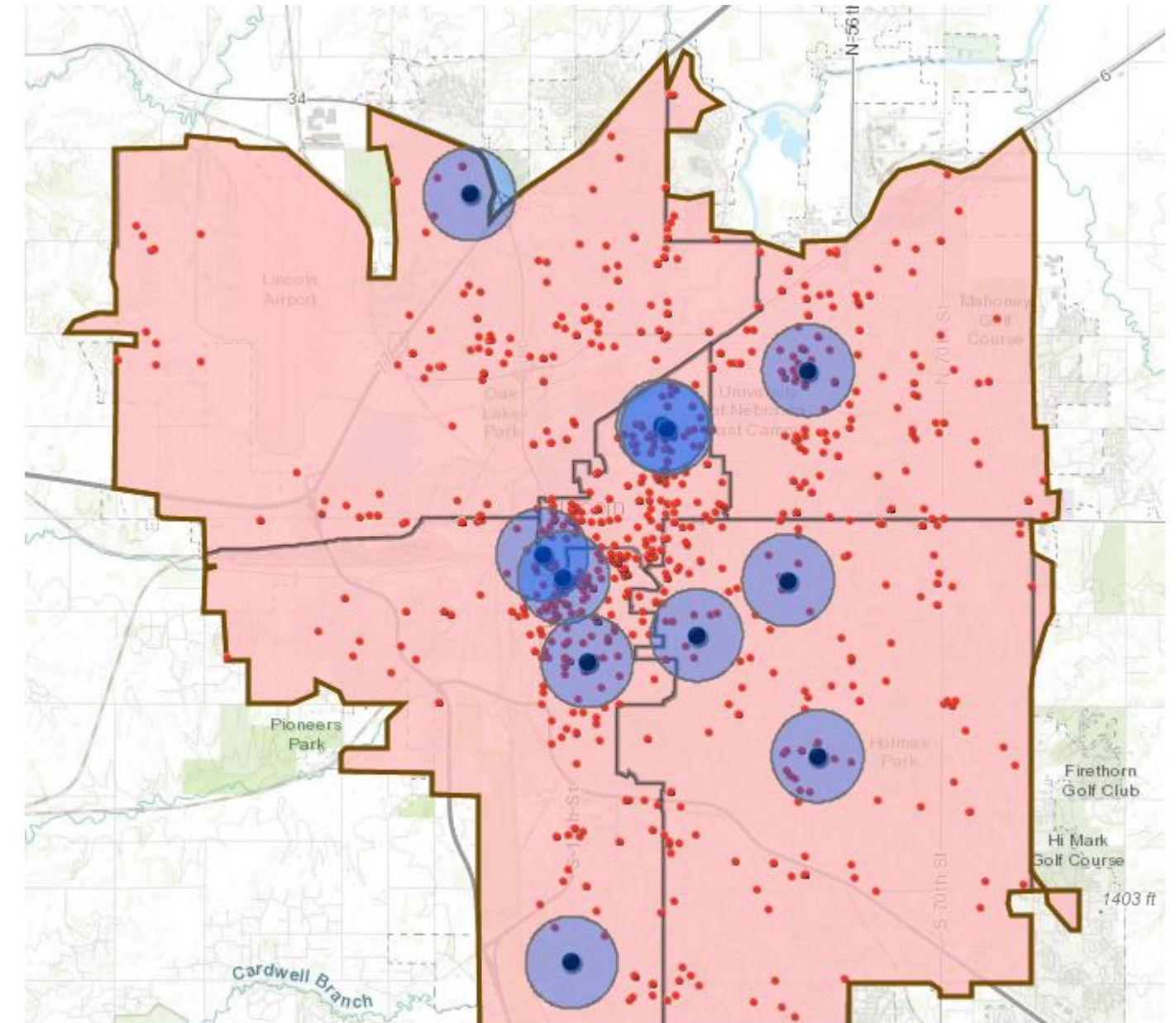
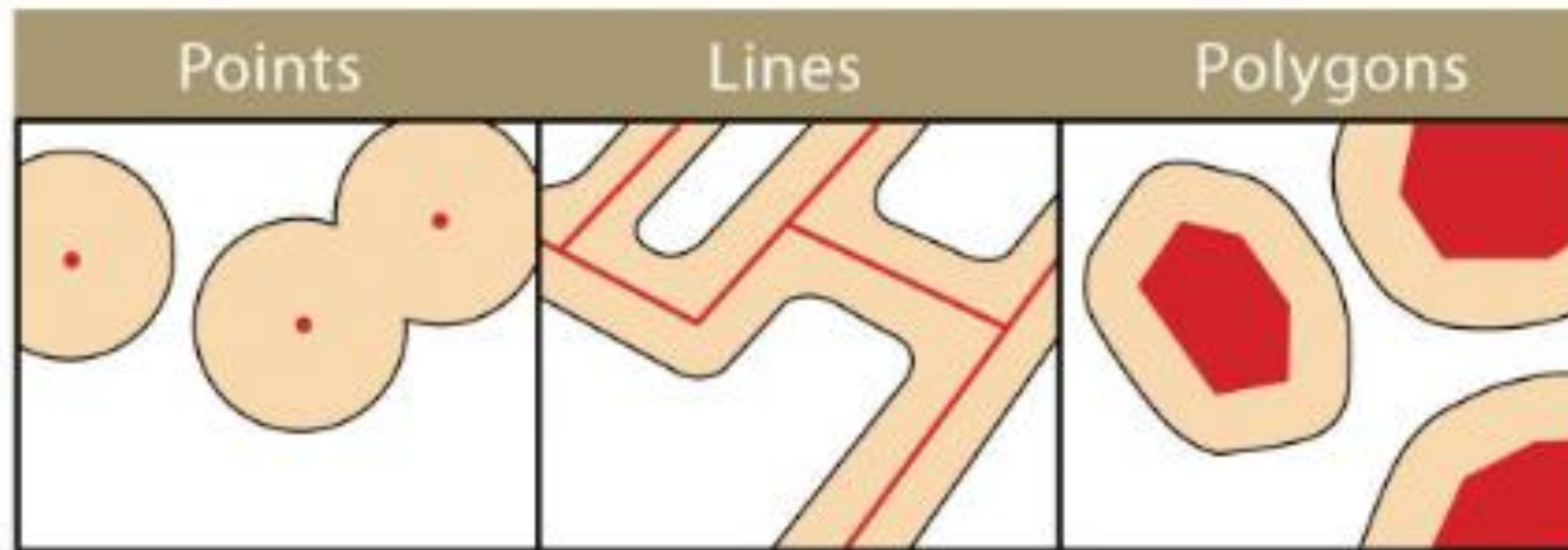


<https://malariajournal.biomedcentral.com/articles/10.1186/s12936-015-0873-2>

Data analysis

**Analysis /
Processing**

- Proximity analysis:** creates a zone of a specified distance around a geographic feature (point, line, or polygon) to identify areas within its influence.

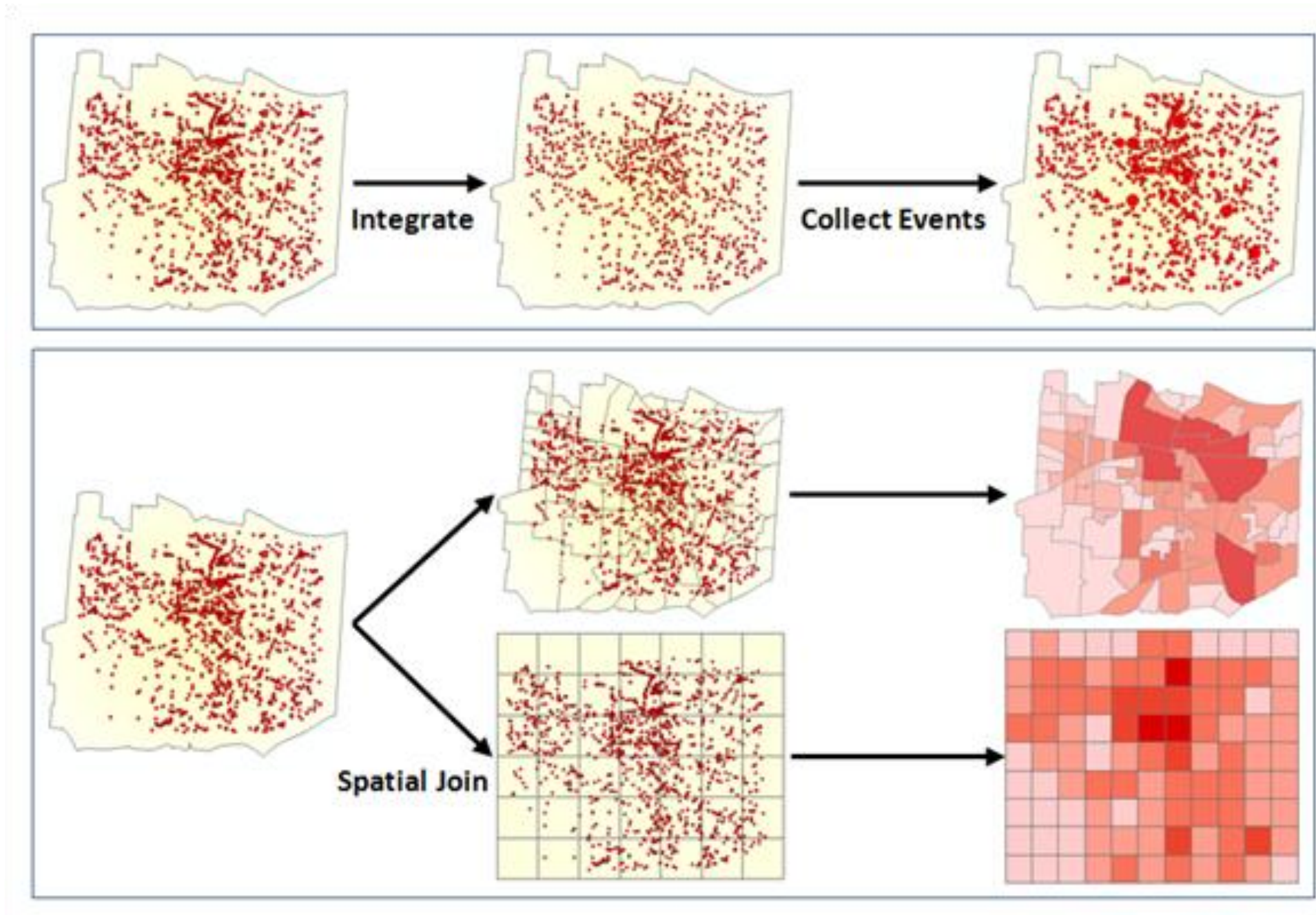


<https://support.esri.com/de-de/knowledge-base/problem-point-features-in-an-overlapping-buffer-area-ar-000018799>

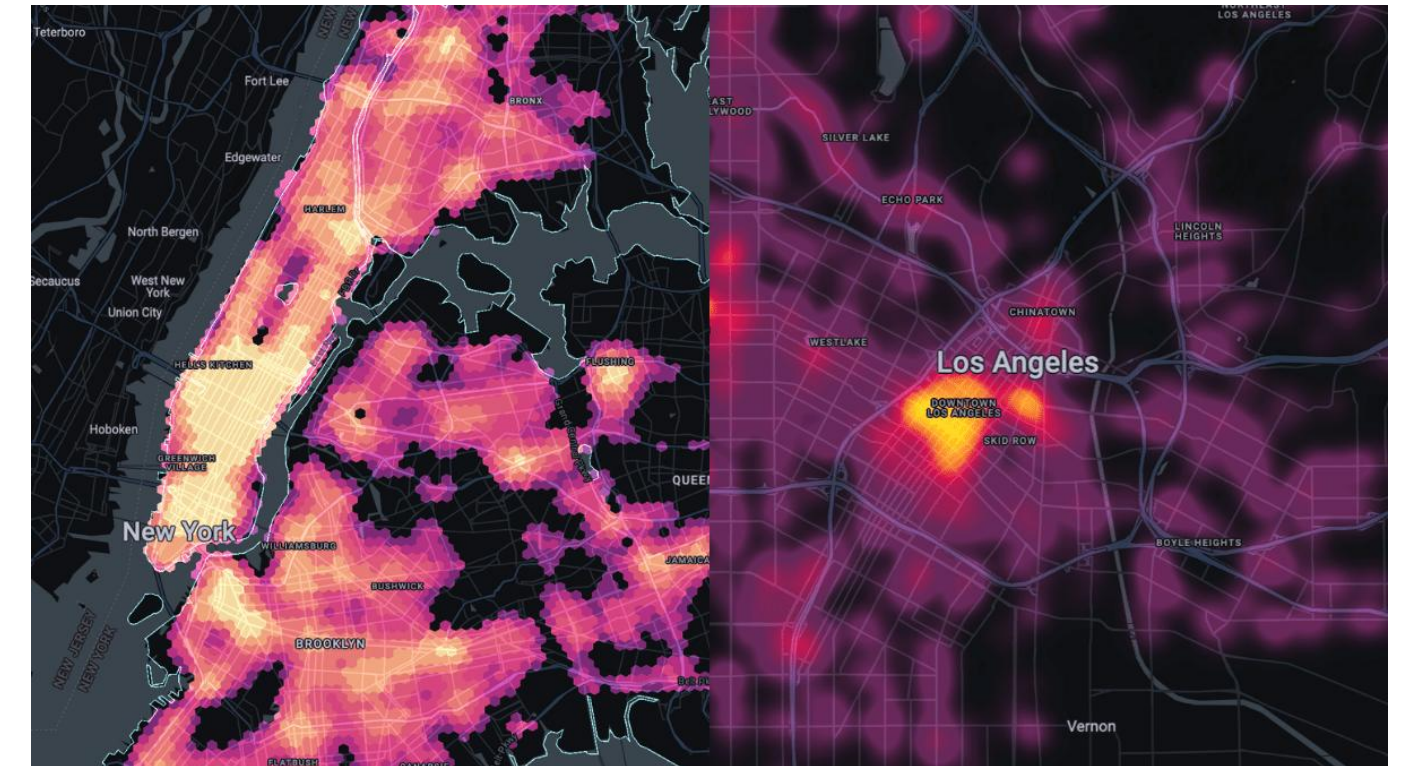


Data analysis

- **Hot spot analysis:** identify statistically significant clusters of high or low values in a dataset.



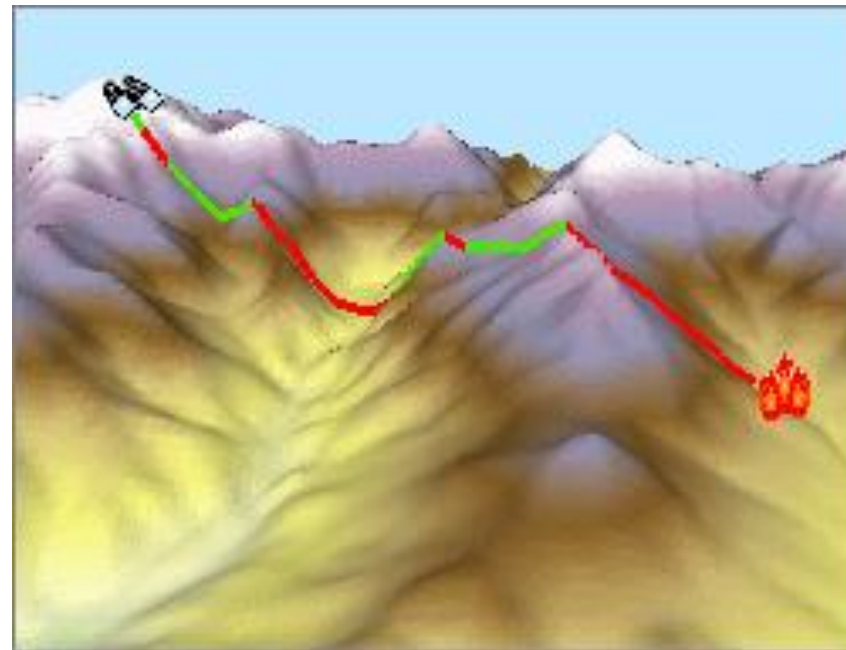
<https://desktop.arcgis.com/de/arcmap/latest/tools/spatial-statistics-toolbox/n-how-hot-spot-analysis-getis-ora-gi-spatial-stati.ntm>



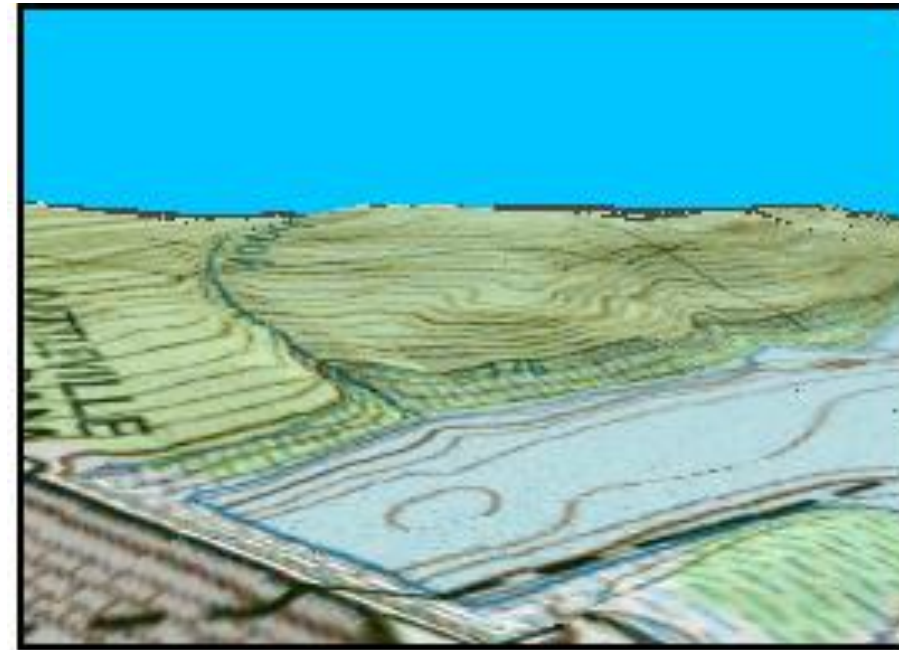
<https://carto.com/glossary/hotspot-analysis>

Data analysis

- Surface Creation and Analysis:** Creating and analyzing surfaces from data points to understand terrain or other continuous phenomena.



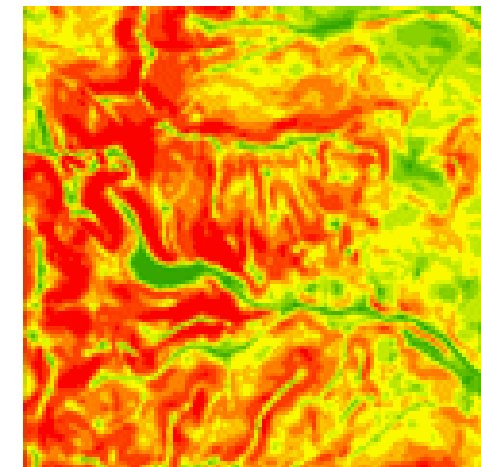
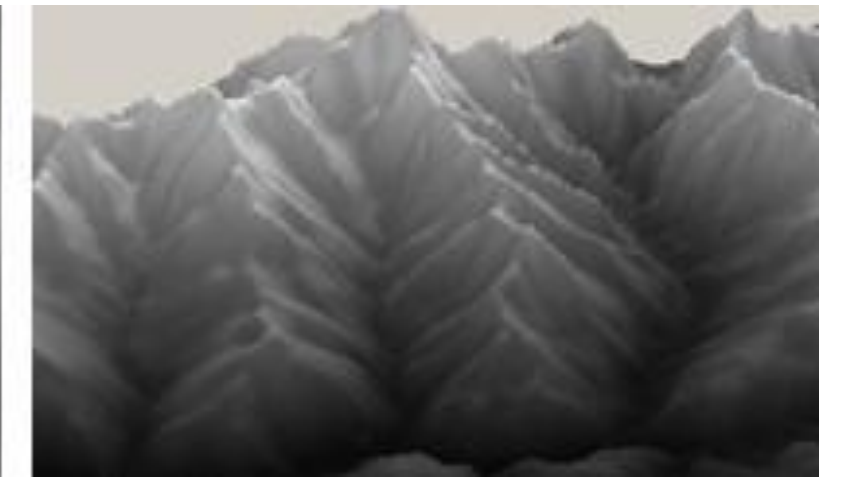
Line-of-sight



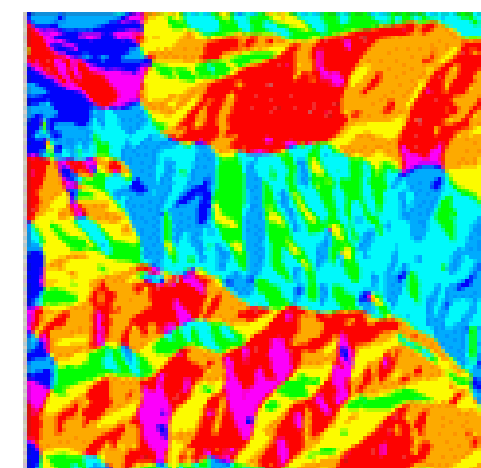
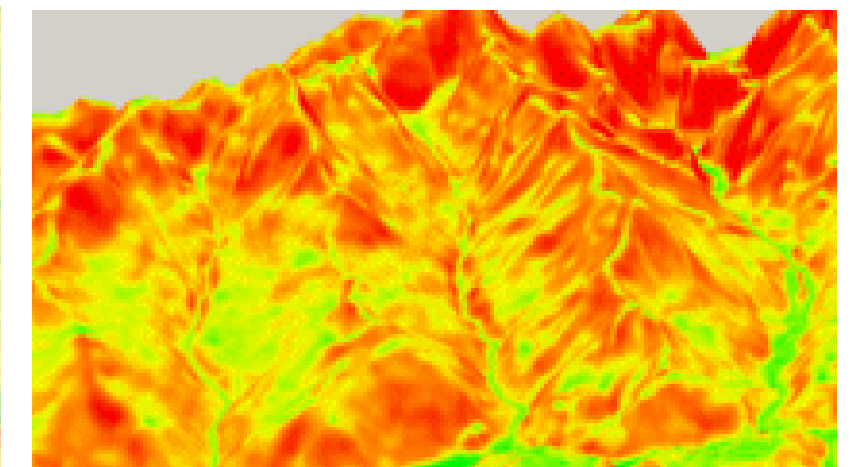
Volume



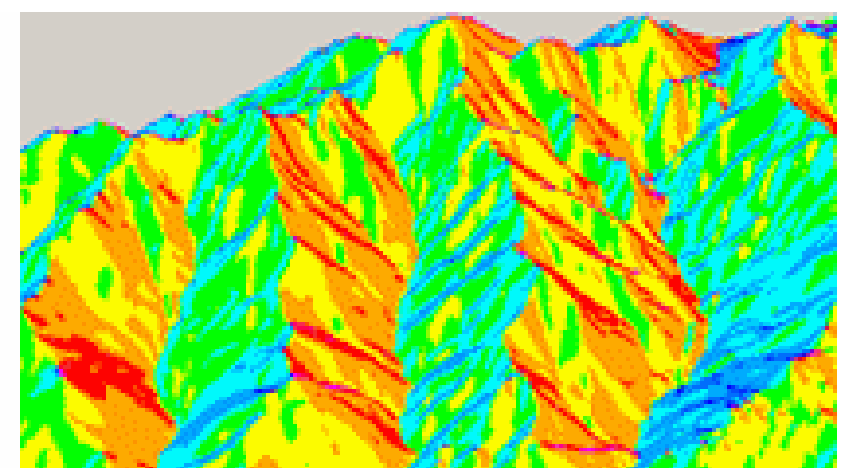
Elevation



Slope



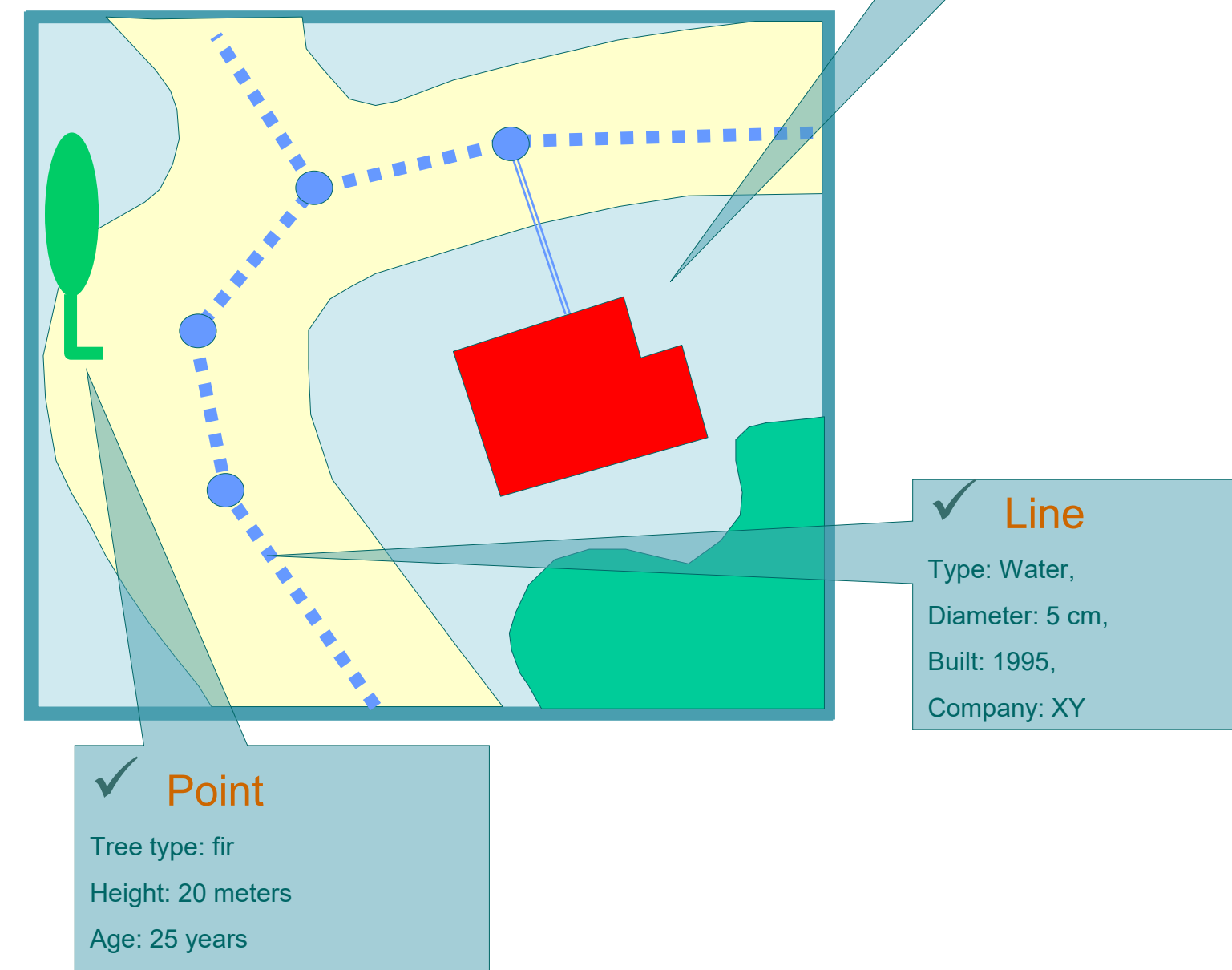
Aspect



Data analysis

- **Table and Attribute Analysis:** Managing and analyzing the attribute data associated with geographic features to extract meaningful information.

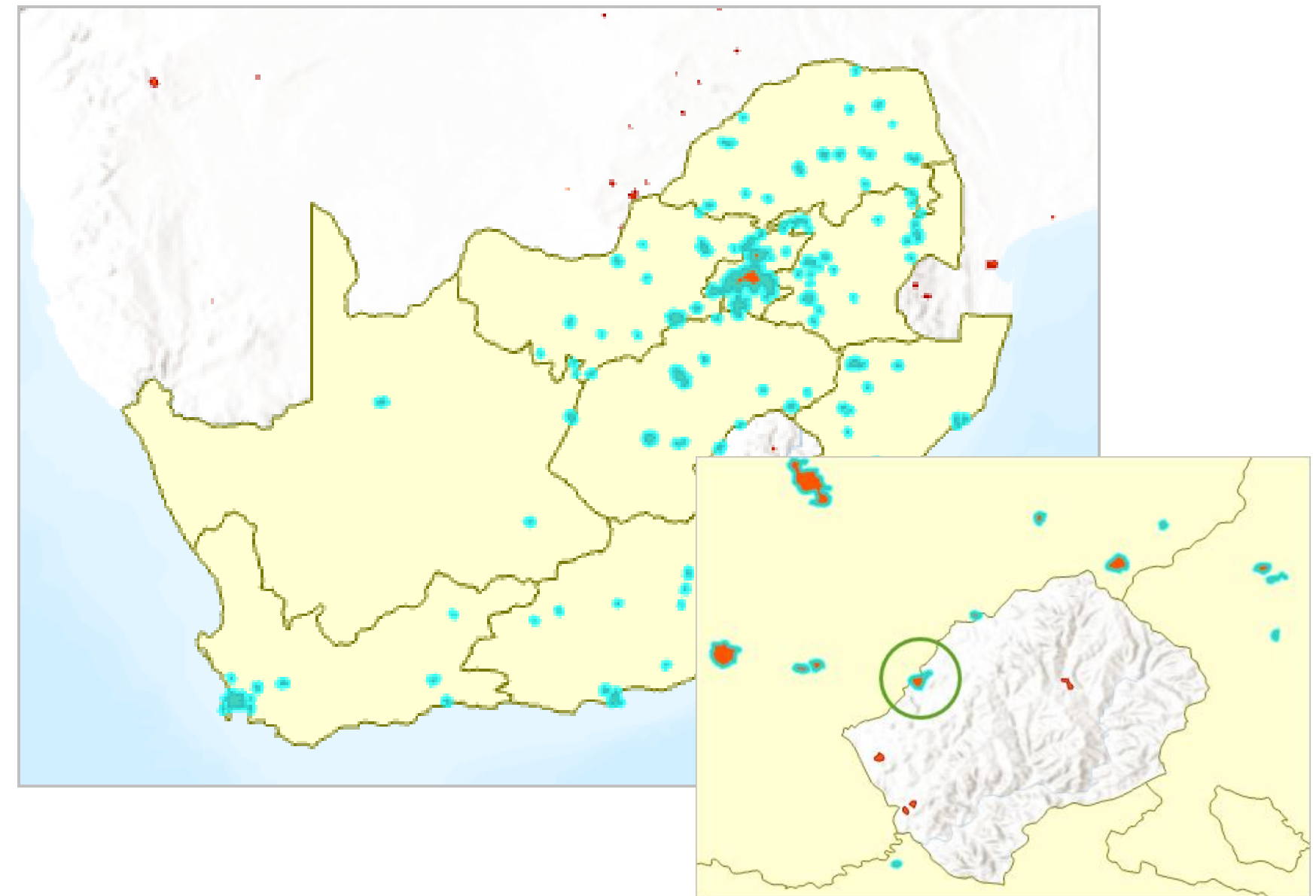
FID	Parcel ID	Zoning	Address	Zip Code	State	Tax Region
0	8618308030	Residential	7228 STREAMSIDE DR	80525	CO	2101
1	9624125001	Residential	7605 S COUNTY RD 13	80527	CO	2019
2	8618306004	Residential	7318 SILVER MOON LN	80525	CO	2101
3	8618306026	Residential	7319 SILVER MOON LN	80525	CO	2101
4	8618405075	Residential	1655 STREAMSIDE DR	80525	CO	2100
5	8618308052	Residential	1300 STREAMSIDE CT	80525	CO	2101
6	8618308032	Residential	7312 STREAMSIDE DR	80525	CO	2101
7	8618310073	Residential	1606 GREENSTONE TR	80525	CO	2100
8	8618306015	Residential	1401 WHITE PEAK CT	80525	CO	2101
9	8618306014	Residential	7507 GREENSTONE TR	80525	CO	2101
10	8618308042	Residential	7514 GOLD HILL CT	80525	CO	2101
11	8618308043	Residential	7515 GOLD HILL CT	80525	CO	2101
12	8618308062	Residential	7119 SILVER MOON LN	80525	CO	2101
13	8618405104	Residential	7513 BLUE WATER CT	80524	CO	2100



Data analysis

Analysis / Processing

- Selecting and Extracting Data:** Isolating specific features or data subsets from larger datasets based on spatial or attribute criteria.



Data visualisation

- A map is a two-dimensional, symbolic representation of a selected area, such as a part of the Earth's surface, to show the location of features, distances, and shapes in a simple, visual way.

- **Key Characteristics**

- **Symbolic Representation:**

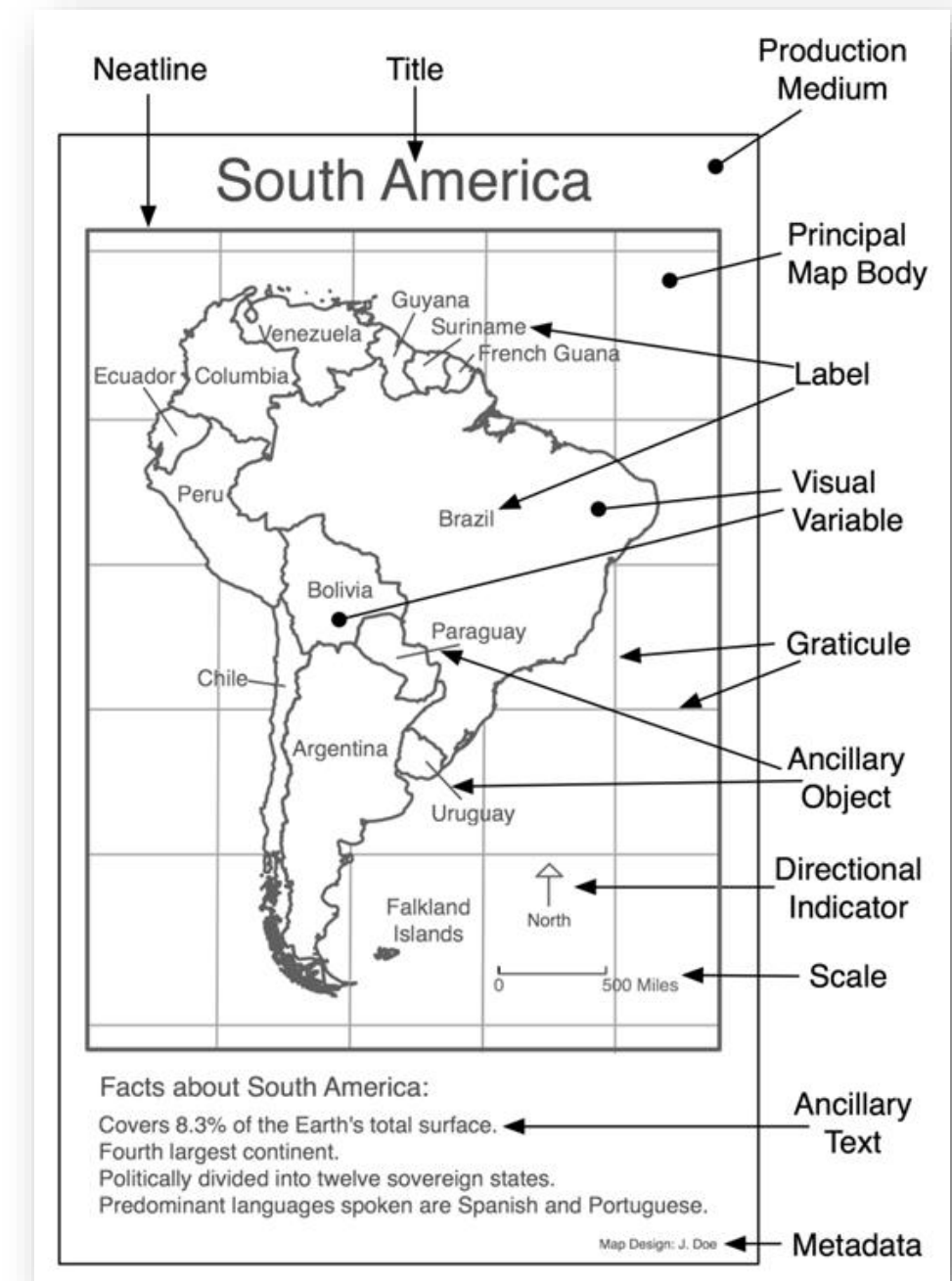
- Maps use symbols, colors, and text to depict real-world features like rivers, roads, buildings, and boundaries on a flat surface.

- **Visual Information:**

- They provide graphical information about a place, helping people to understand sizes, shapes, and locations of various elements.

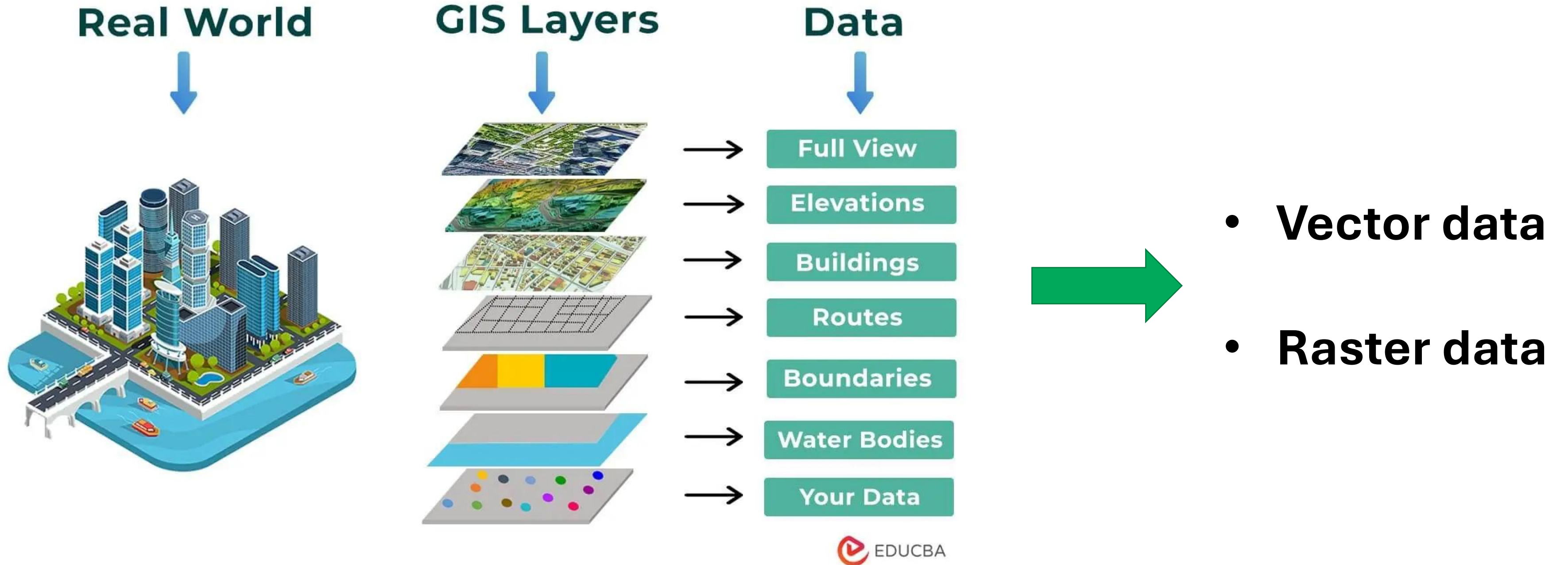
- **Scalability:**

- Maps are scaled down to fit a flat surface, allowing for the representation of very large areas, from a neighborhood to the entire world.



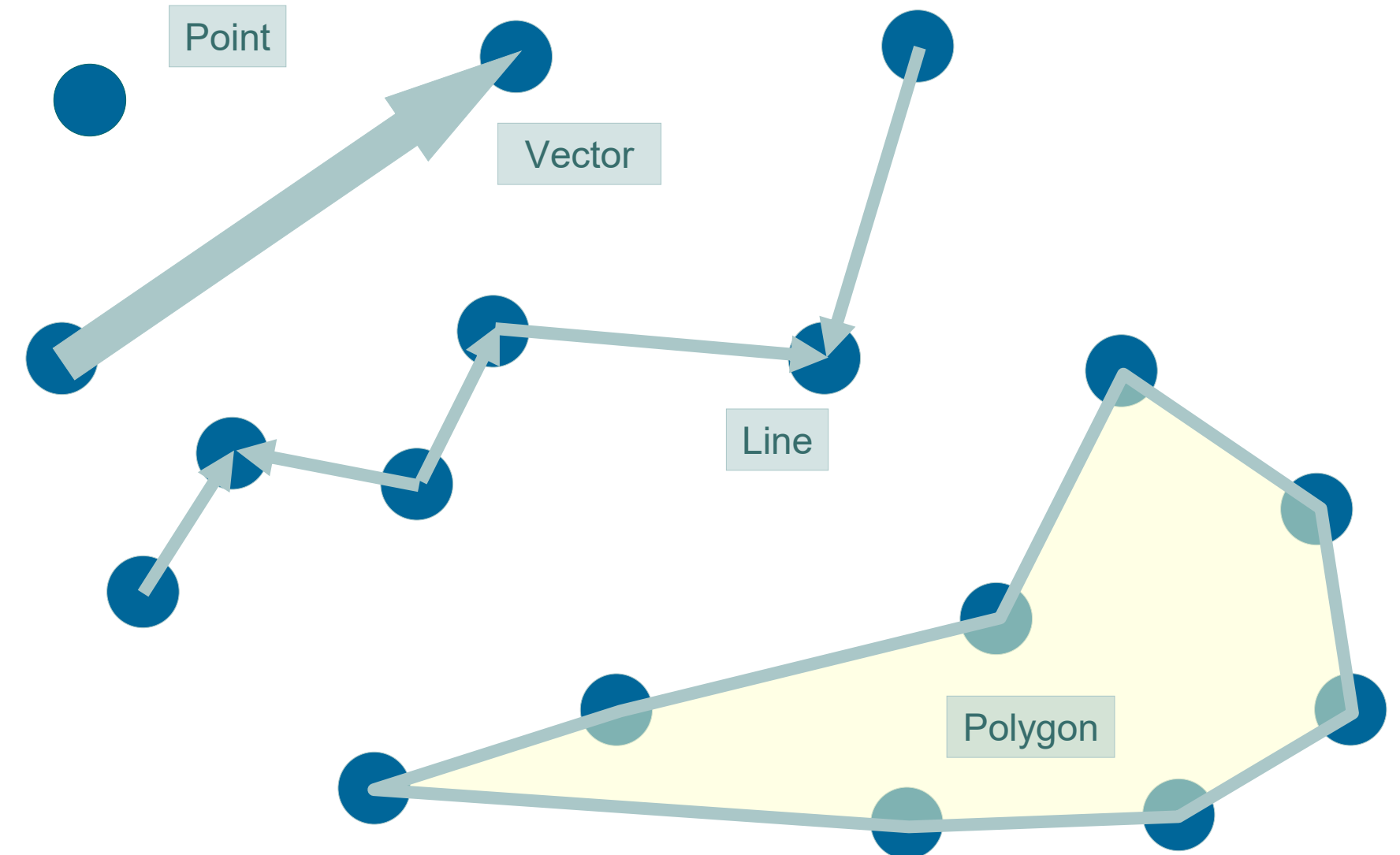
<https://open.maricopa.edu/gist/chapter/4-2-map-design-and-map-elements/>

From Real World to Geodata



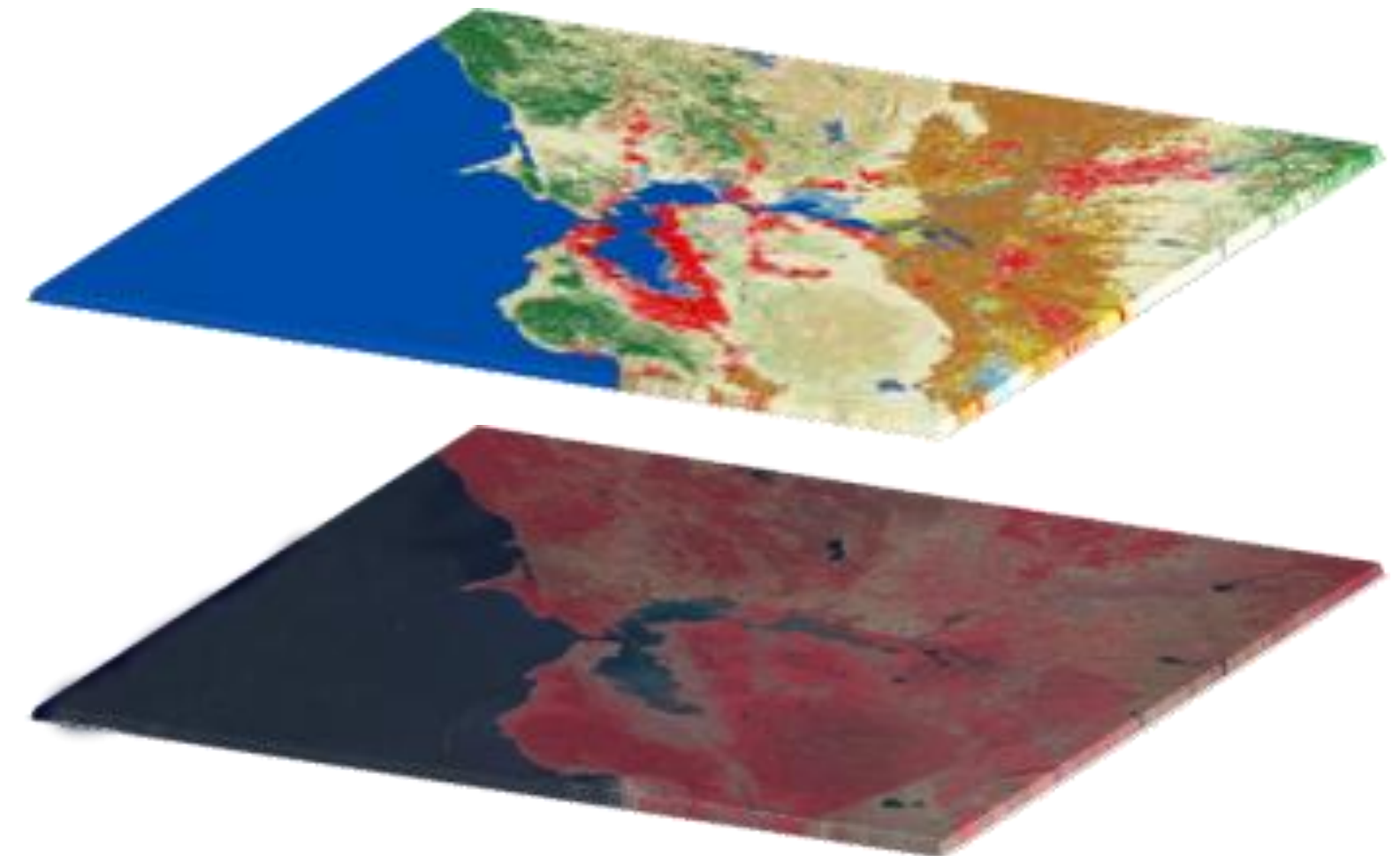
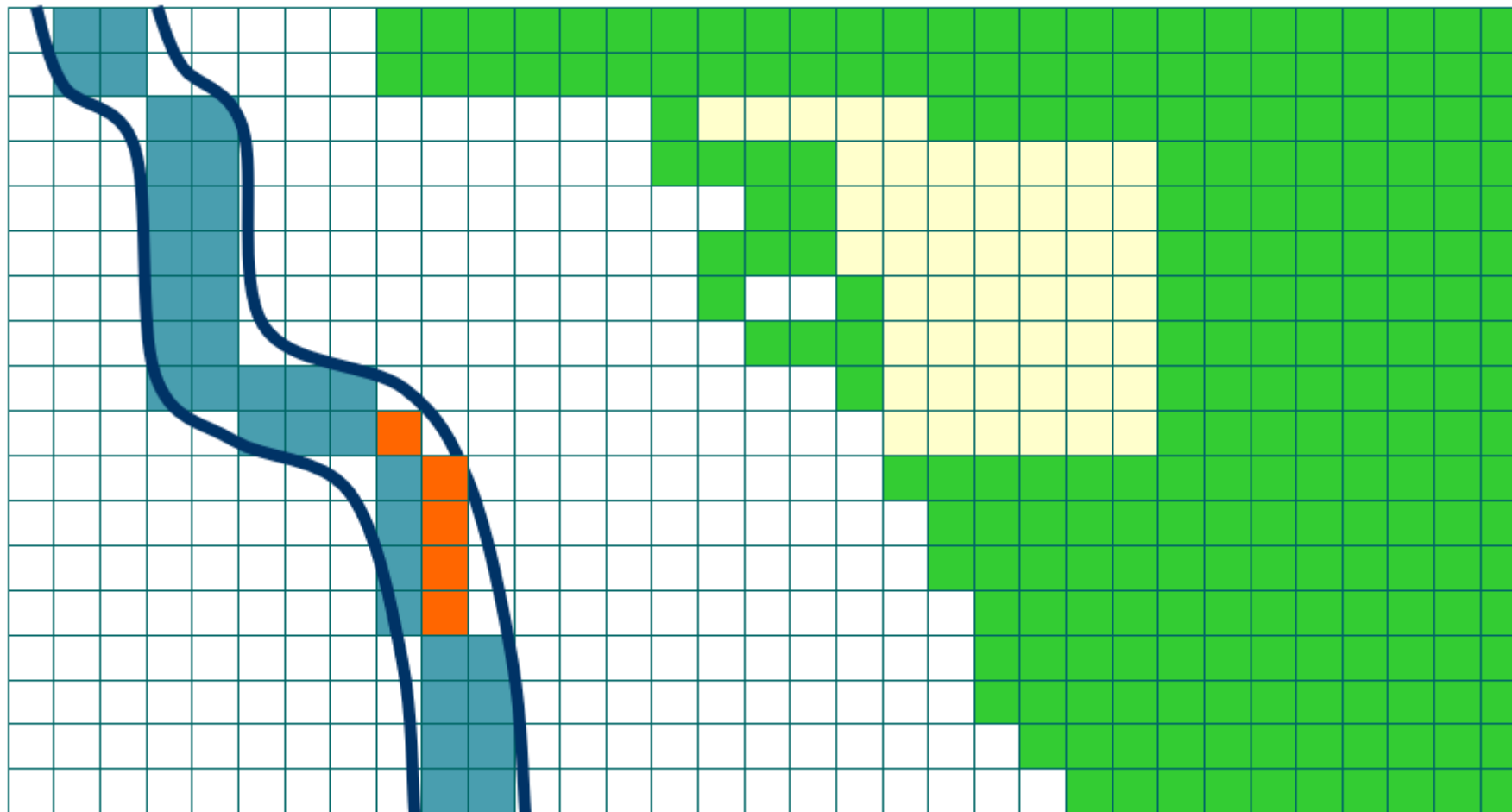
Vector data

- **Points, lines, polygons:** vector graphics are comprised of **vertices and paths**.
 - Points are simply XY coordinates.
 - Vector lines connect each vertex with paths.
 - Vector polygon: join a set of vertices in a particular order and close it.



Raster data

- **Raster data** is made up of pixels (also referred to as grid cells). They are usually regularly spaced and square
- **Discrete rasters** have distinct themes or categories. For example, one grid cell represents a land cover class or a soil type.



Geodata Analysis and Data Collection for Empowering Women in Turkana

- **How can GIS help for empowering women in Turkana?**
 1. Collect data representing the driving factors for inequalities or problems!
 2. Analyse these data and their spatial relationships!
 3. Present data to local authorities to make problems visible!

Discussion

- **Think about topics which affect women in their daily life?**
- **How can we represent these topics with geodata?**

Groups of 4 persons

Time: 10 – 15 minutes



Benefits of GIS for teaching in schools

- **Spatial reasoning and problem-solving:** GIS software allows students to analyze geographic data, recognize patterns, and solve their own problems. Instead of just reading maps, they create and interpret their own thematic maps.
- **Visualization of complex data:** GIS not only visualizes geographic information (such as rivers or cities), but also links it to factual data (e.g., population density, income, pollution). This makes abstract relationships such as the correlation between urban density and traffic volume tangible.
- **Increase motivation:** The interactive and hands-on work with GIS tools motivates students. They can use real-world, up-to-date data to examine local or global issues, making lessons more relevant and exciting.
- **Promotion of digital skills:** The use of GIS software trains important digital skills that are in demand in many professional fields. This includes data management, analysis, critical media literacy, and presentation creation.
- **Inquiry-exploratory learning:** GIS supports a teaching approach where students hypothesize, collect and analyze data to find answers. This promotes independent, scientific work.

Possible applications and examples

- GIS technology can be applied in all geographical subject areas, for example:
 - **Urban Geography:** Students can analyze the development of cities by comparing historical satellite imagery or examining data on land use, infrastructure, and population distribution in different neighborhoods.
 - **Climate change and environment:** GIS allows students to visualize and analyze the spread of deserts, the retreat of glaciers, or the distribution of greenhouse gas emissions on a world map. You can create buffer zones around nature reserves or simulate the effects of flooding.
 - **Economic geography:** Learners can examine the location factors of companies by comparing data such as proximity to highways, labor availability, or purchasing power in a region.
 - **Demography:** Pupils can map population migrations, age structures or the distribution of ethnic groups in a region and thus explore relationships between social and geographical factors.
 - **Disaster management:** By layering layers of data (e.g., weather data, topography, infrastructure), students can identify potential risk zones for natural disasters and plan possible evacuation routes.

**Start software:
QGIS Desktop 3.40.11
→ Use „Search“**

Day 1: Visualising geodata

QGIS, Loading data, symbolising

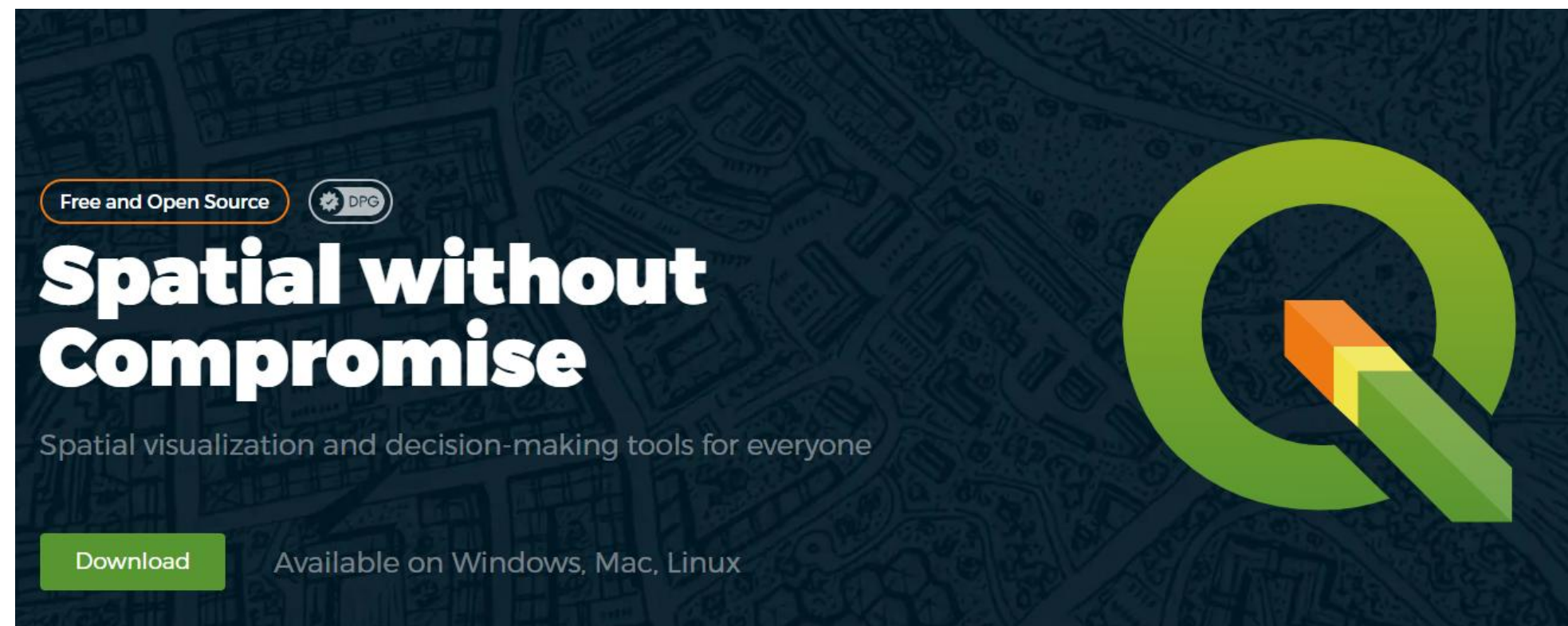
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Software

Software: C:\GIS_training\Software

- <https://qgis.org>

QGIS (previously known as Quantum GIS) is a free and **open-source geographic information system (GIS)** software. It's a cross-platform desktop application that allows users **to create, view, edit, analyze, and publish geospatial information**. As an open-source project, QGIS is developed and maintained by a global community of volunteers and organizations.



Download QGIS

- **Long Term Release:** → stable and unchanged platform for companies and organizations

Download QGIS for your platform

The current version is QGIS 3.42.0 'Münster' and was released on 2025-02-21.

The long-term builds currently provide 3.40.4 'Bratislava'. Long Term Release (LTR) builds are intended for those who value stability over having the latest features. If you are unsure which version is best for you, download the LTR.

QGIS is available on Windows, macOS, Linux, Android and iOS.

Online (OSGeo4W) installer:

[OSGeo4W Network Installer](#)

This installer is the best way to keep QGIS up to date, run multiple versions on your system and keep the load on our download servers to a minimum. [Learn more.](#)

Offline (Standalone) installers:

[Long Term Version for Windows \(3.40 LTR\)](#) [Latest Version for Windows \(3.42\)](#)

[Latest Version for Windows \(3.42\) with Qt6 \(experimental\)](#)

[Long Term Version for Windows \(3.40\) with Qt6 \(experimental\)](#)

These installers are for users who wish to easily share the download e.g. putting it on a USB key or network share. [Learn more.](#)

⚠ Since QGIS 3.20 we only ship 64-bit Windows executables.

Other platforms

- Linux
- macOS
- BSD
- Container Images
- Mobile and tablet

Linux

GNU/Linux is a Free operating system built on the same principles that QGIS is built on. We provide installers for many flavors of GNU/Linux binary packages (including rpm and deb packages). Please select your choice of distro below:

- Debian/Ubuntu
- Fedora
- NixOS
- openSUSE
- Mandriva
- Slackware
- Arch Linux
- Flatpak
- Spack

[Linux Installation Instructions](#)

macOS

[Long Term Version for Mac OS \(3.40 LTR\)](#) [Latest Version for Mac OS \(3.42\)](#)

Alternatively, for native support of both Intel x86 and Apple ARM architectures, together with the latest versions of key components (e.g. GDAL, PDAL, GRASS GIS) see [MacPorts Installing Instructions](#)

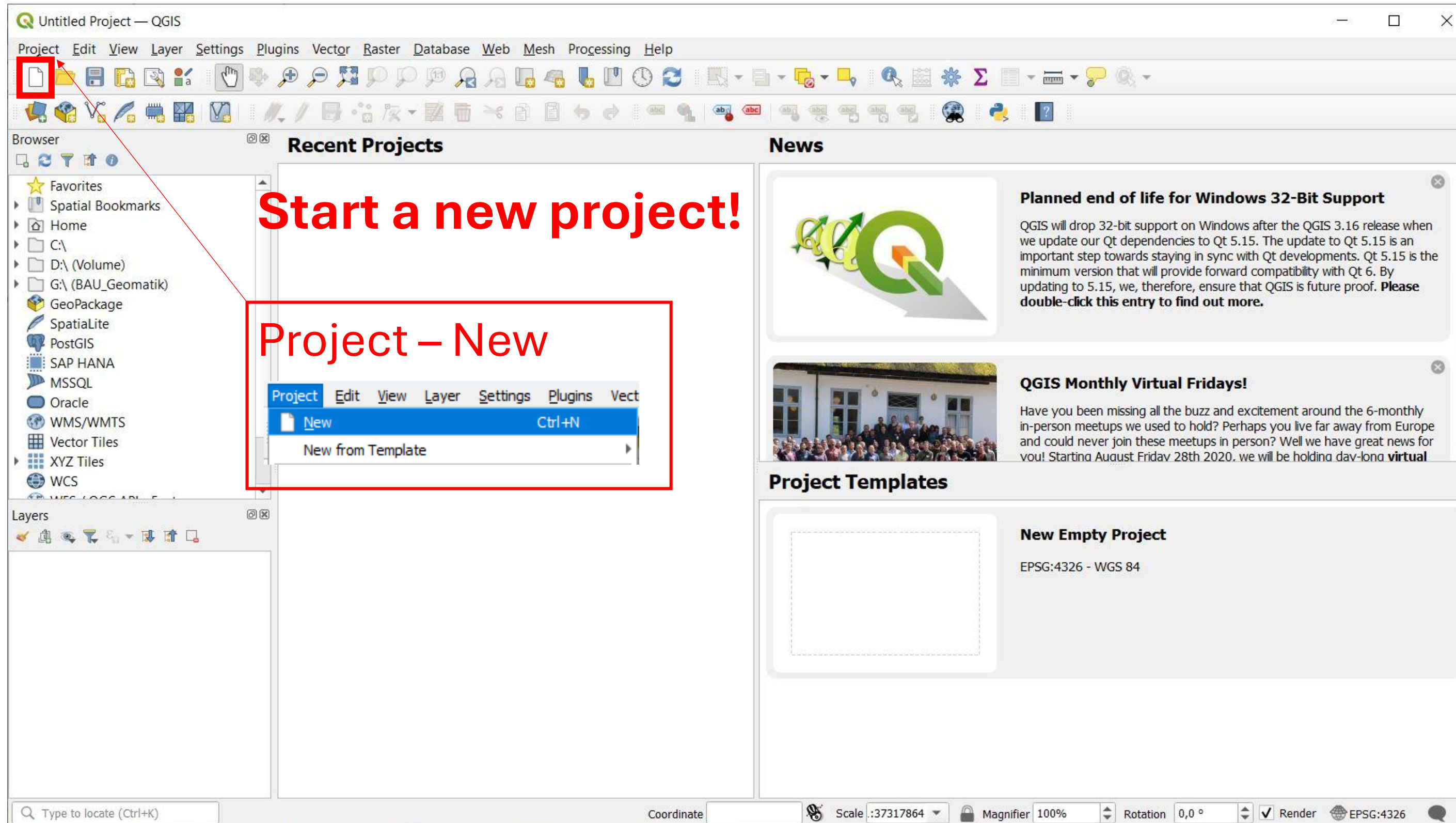
Tips for first launch

After installing QGIS, the first launch attempt may fail due to Apple's security framework.

For macOS Sonoma (14) and earlier: To enable QGIS, command-click on its icon in your Applications folder and select **Open** in the context menu. A confirmation dialog will display where you need to click the **Open** button again. This only has to be done once.

For macOS Sequoia (15) and newer: To enable QGIS, command-click its icon in your Applications folder and select **Open** from the context menu. A warning dialog will appear; click the **Done** button. Next, navigate to **System Settings > Privacy & Security** and scroll to the **Security** section. You should see a message stating that **"QGIS" was blocked to protect your Mac**. Click **Open Anyway**. A confirmation dialog will appear; click **Open Anyway** again. This only has to be done once.

QGIS Desktop



Start a new project!

Project – New

First steps

- **QGIS Desktop**

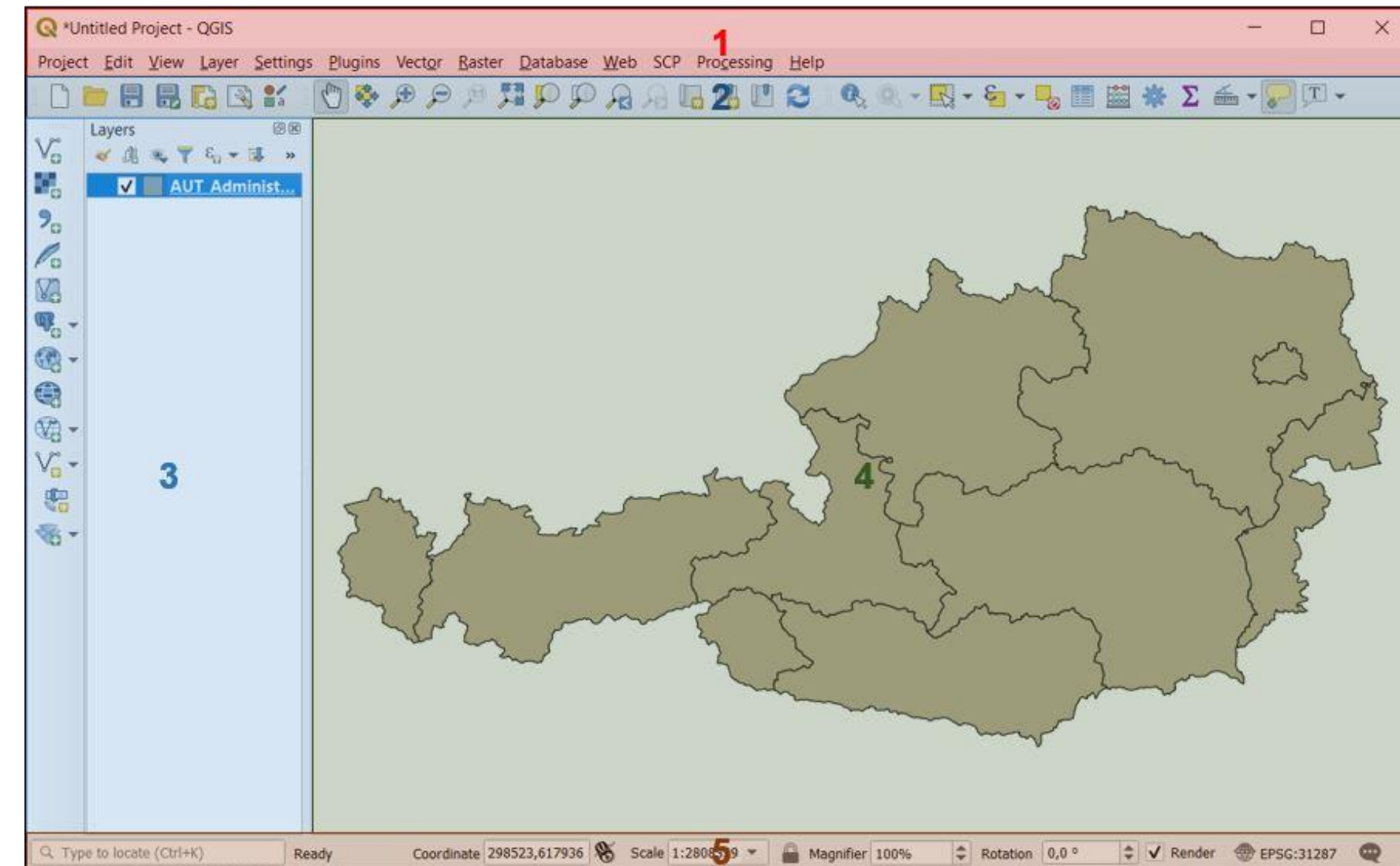
1. The menu bar contains the usual general commands from File to Help.

2. Toolbars contain various functions for editing the data and can be added or removed as required.

3. Under the Layer panel all loaded geodata are listed. The legend for the data can be activated/deactivated or the data can be made visible or invisible.

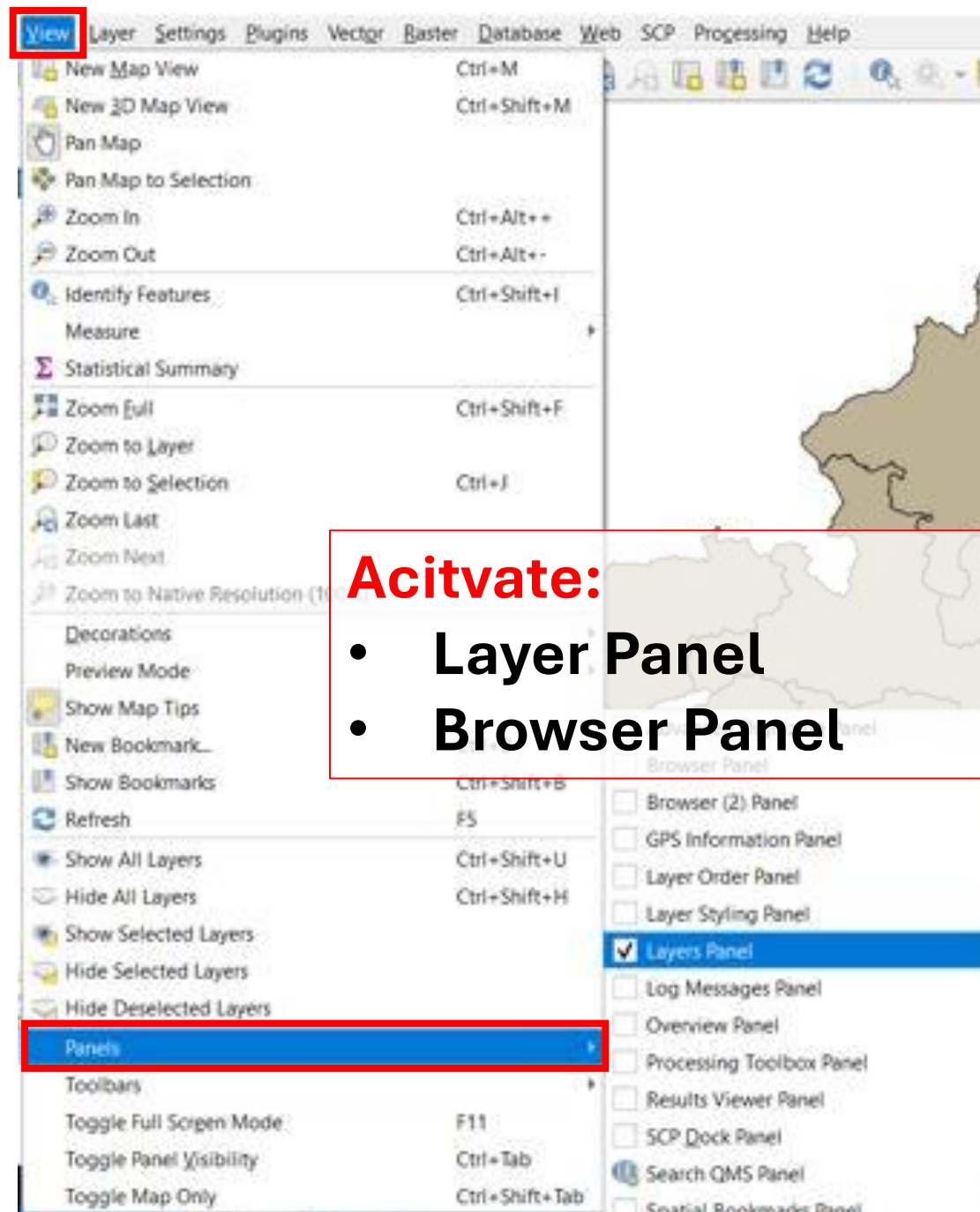
4. The map window shows all loaded data. The sequence of the data is determined via the "Layer" or "Layer Order" panel.

5. In the status bar you will find information about the coordinate reference system (CRS) used or the map projection, the display scale and the coordinates where the cursor is located.

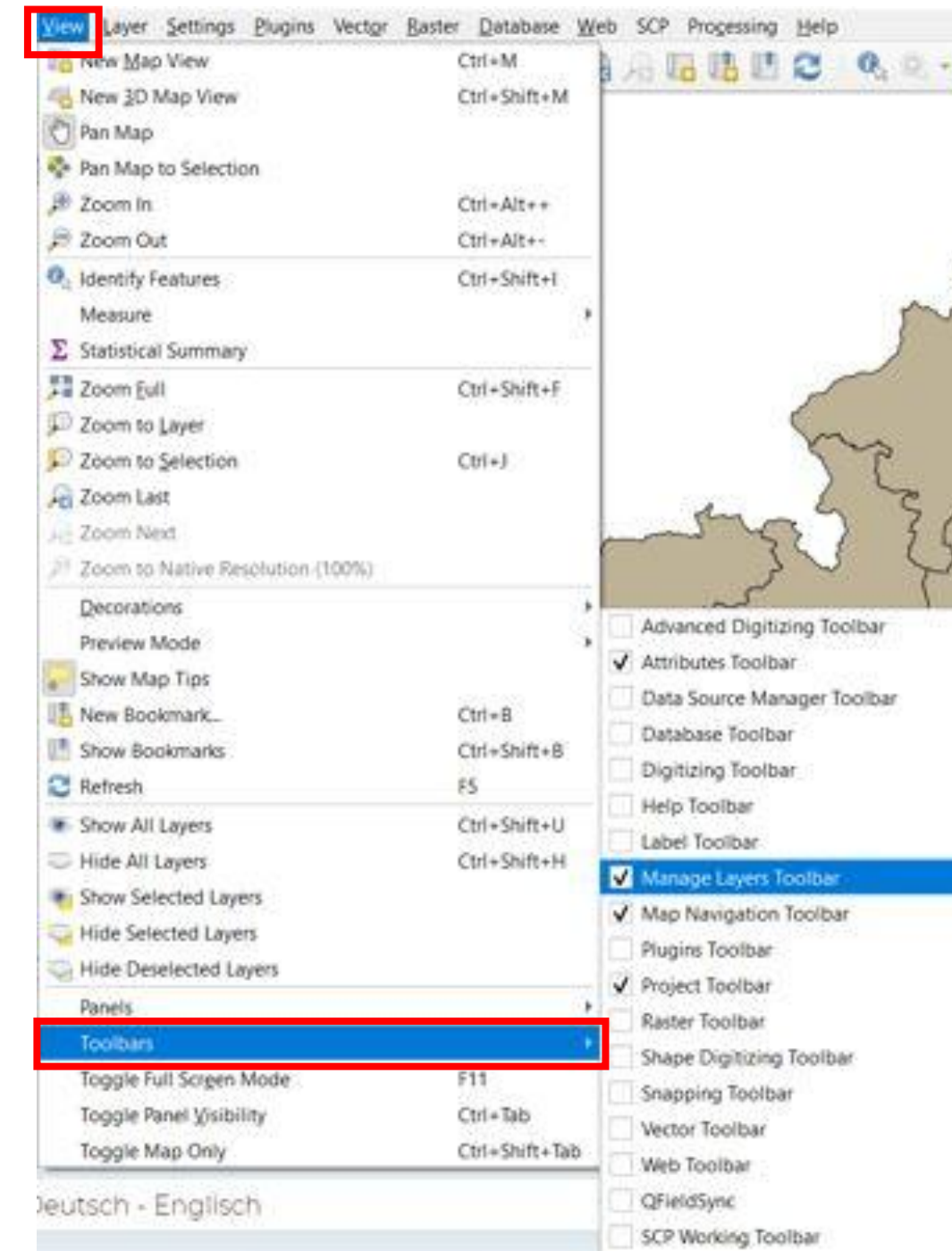


Panels and Toolbars

- View – Panels



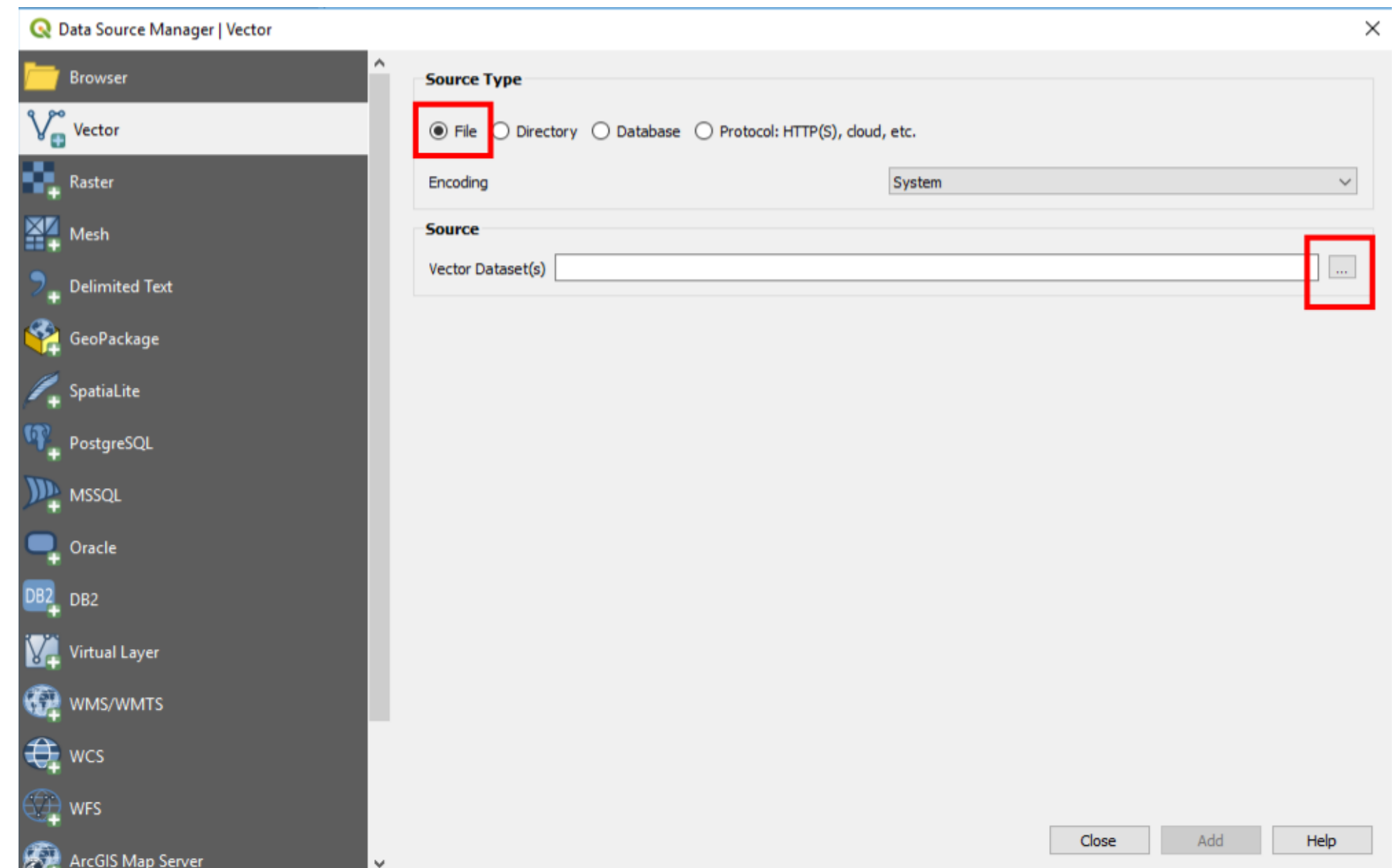
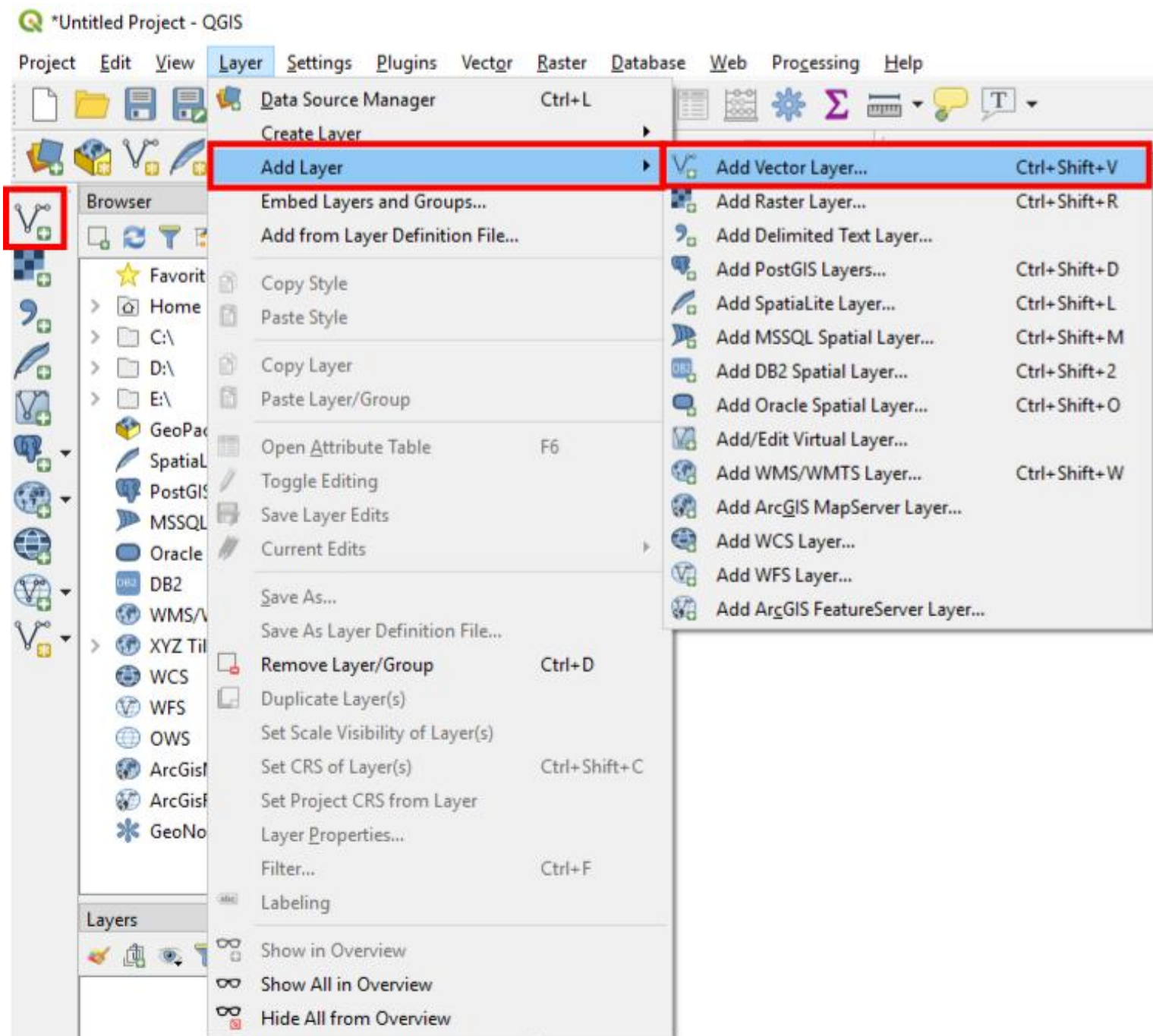
- View – Toolbars



Add data

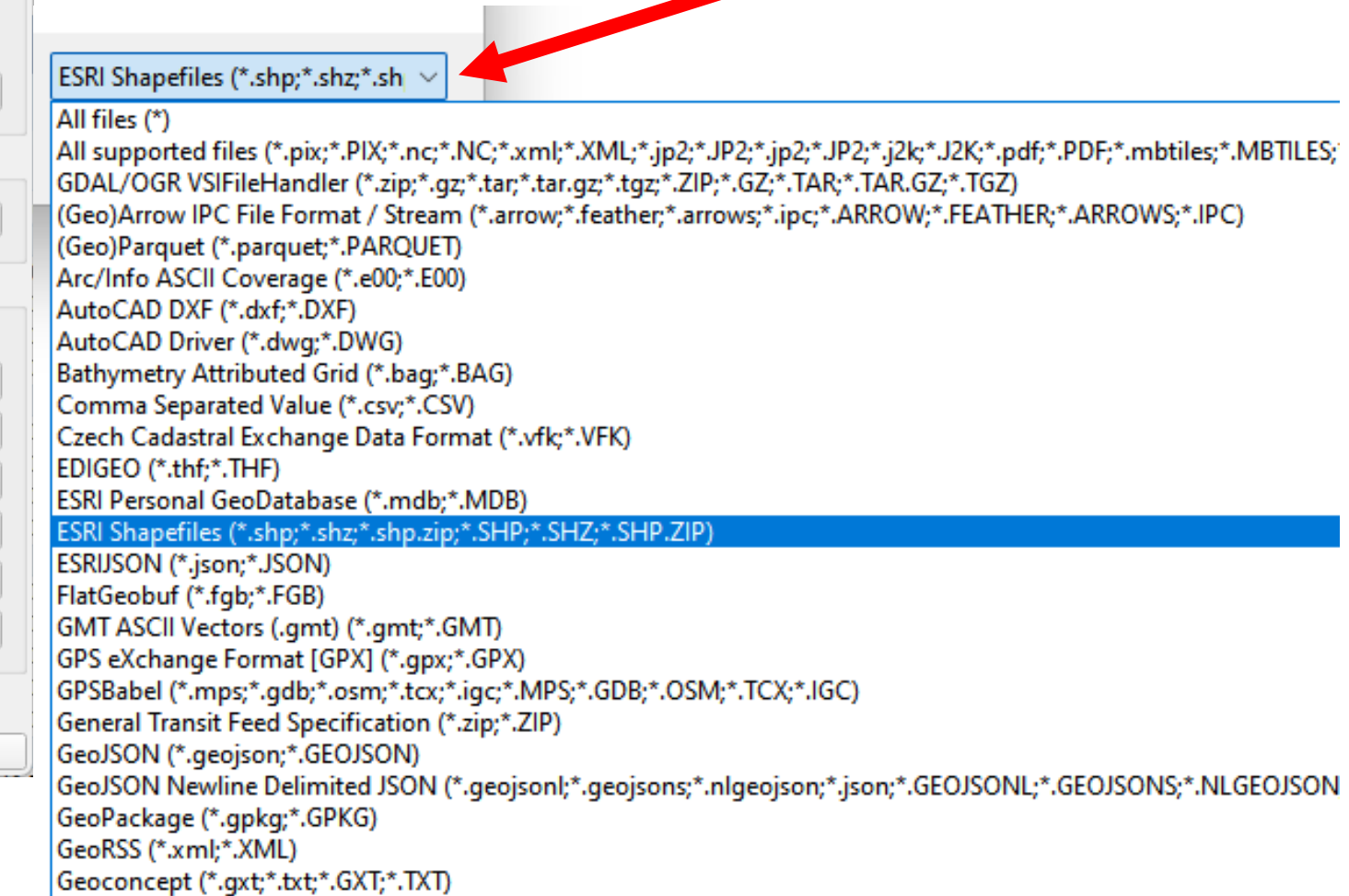
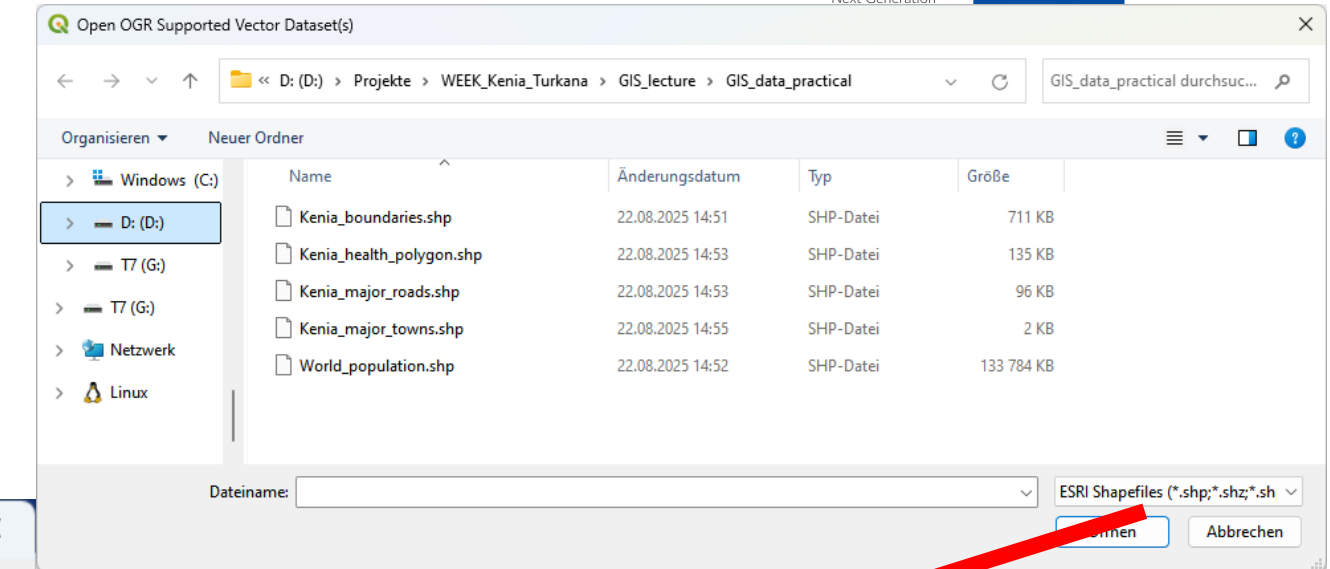
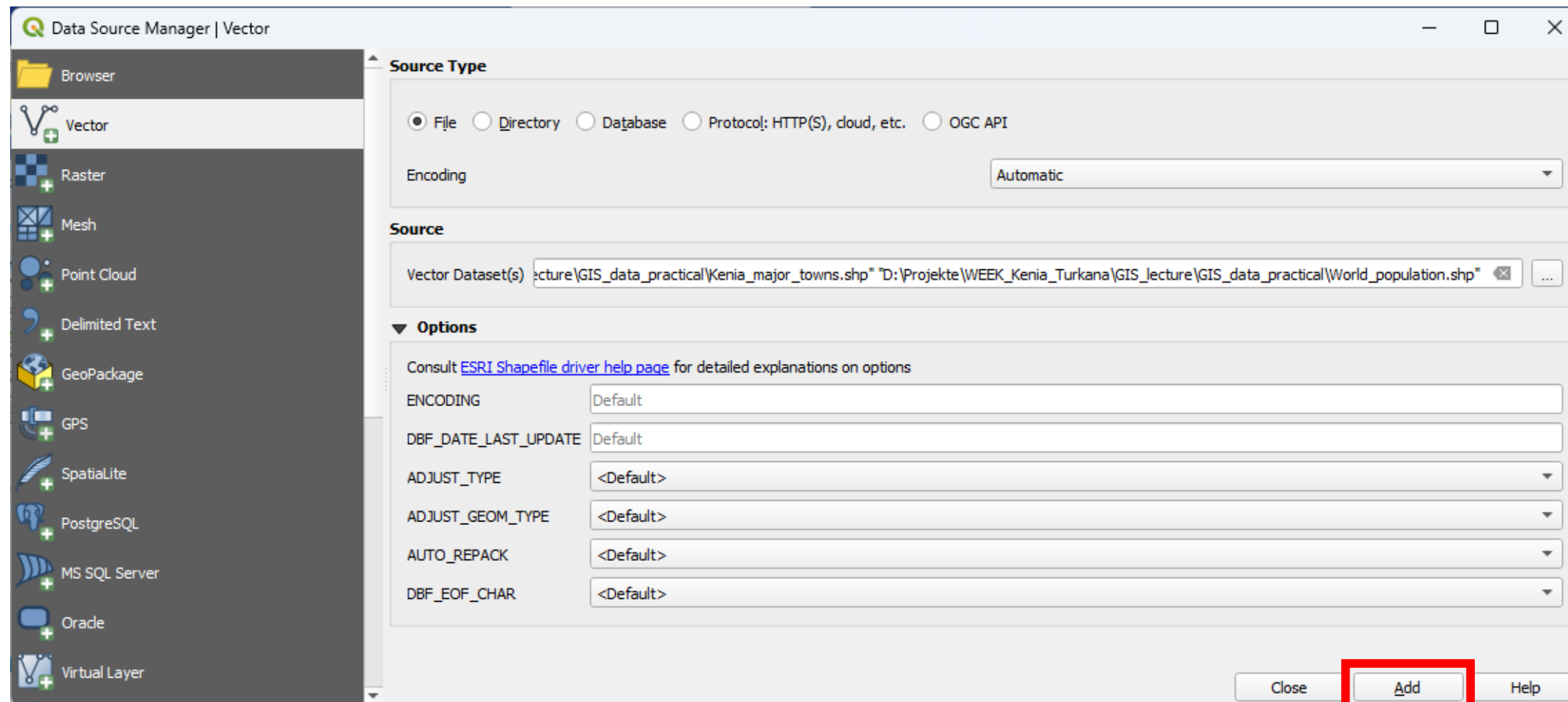
Data: C:\GIS_training\GIS_data_practical

- Load various geodata



Add data

- Load various geodata



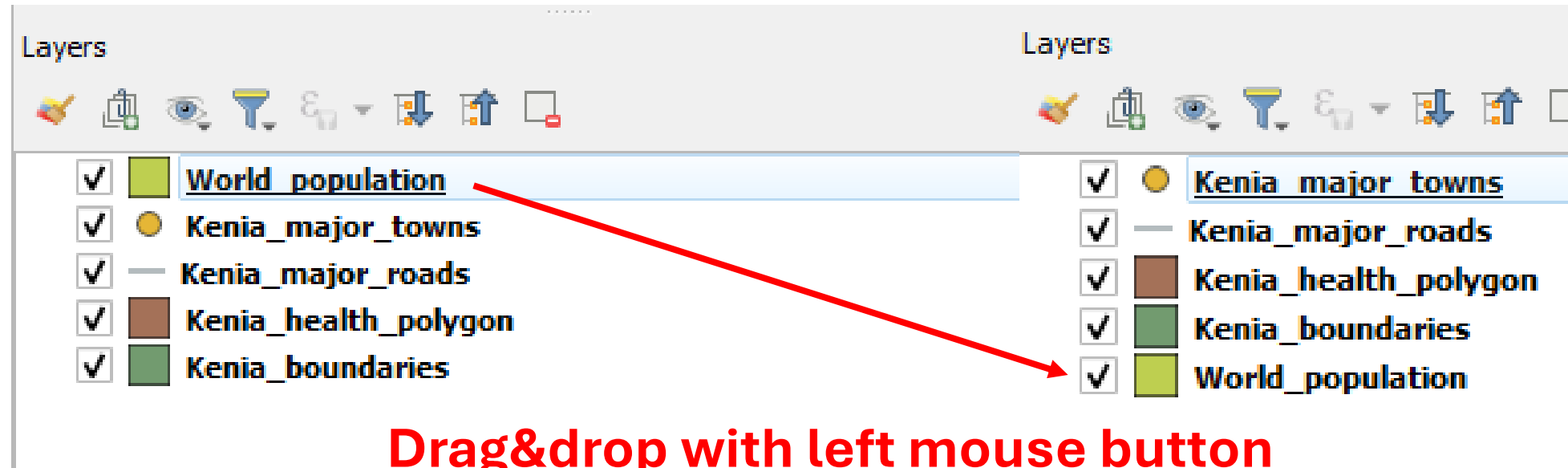
Name	Änderungsdatum	Typ	Größe
Kenia_boundaries.shp	22.08.2025 14:51	SHP-Datei	711 KB
Kenia_health_polygon.shp	22.08.2025 14:53	SHP-Datei	135 KB
Kenia_major_roads.shp	22.08.2025 14:53	SHP-Datei	96 KB
Kenia_major_towns.shp	22.08.2025 14:55	SHP-Datei	2 KB
World_population.shp	22.08.2025 14:52	SHP-Datei	133 784 KB

→ Look for ESRI Shapefiles

→ Shape-File (SHP) is a special geodata format

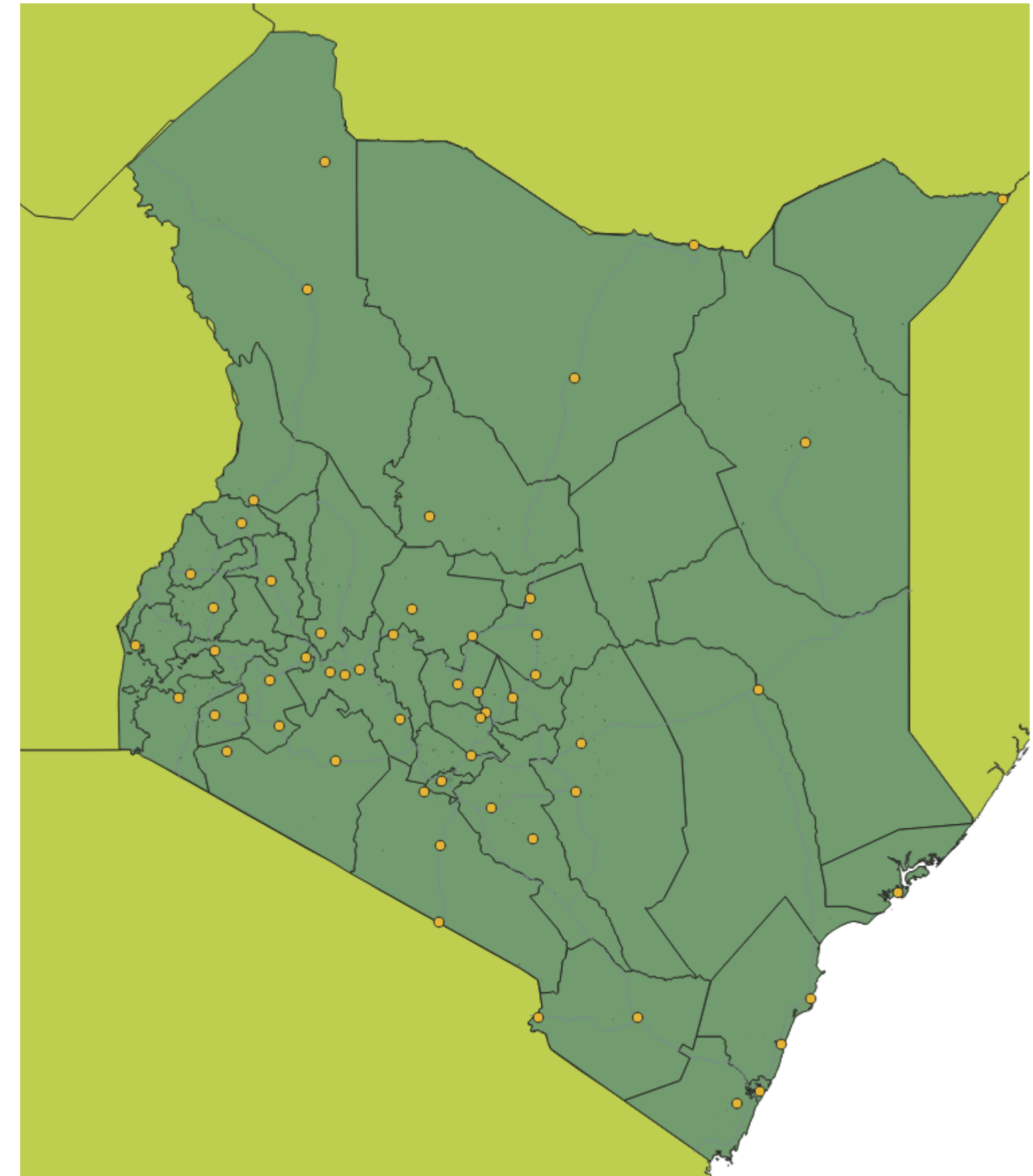
Displaying data

- Change drawing order



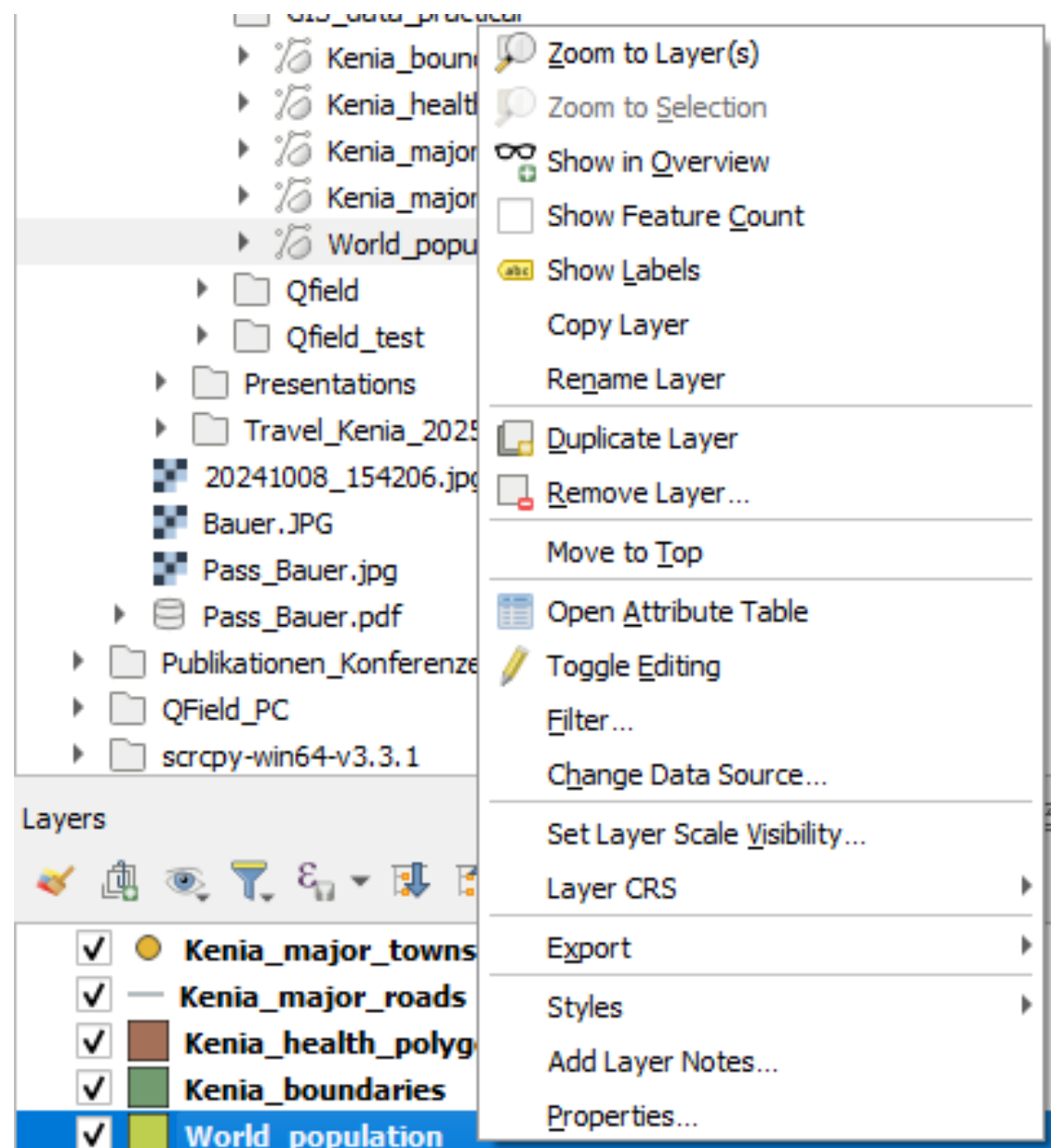
**Drag&drop with left mouse button
(hold button)**

- Map Navigation Toolbar



Displaying data

• Layer Context-Menu



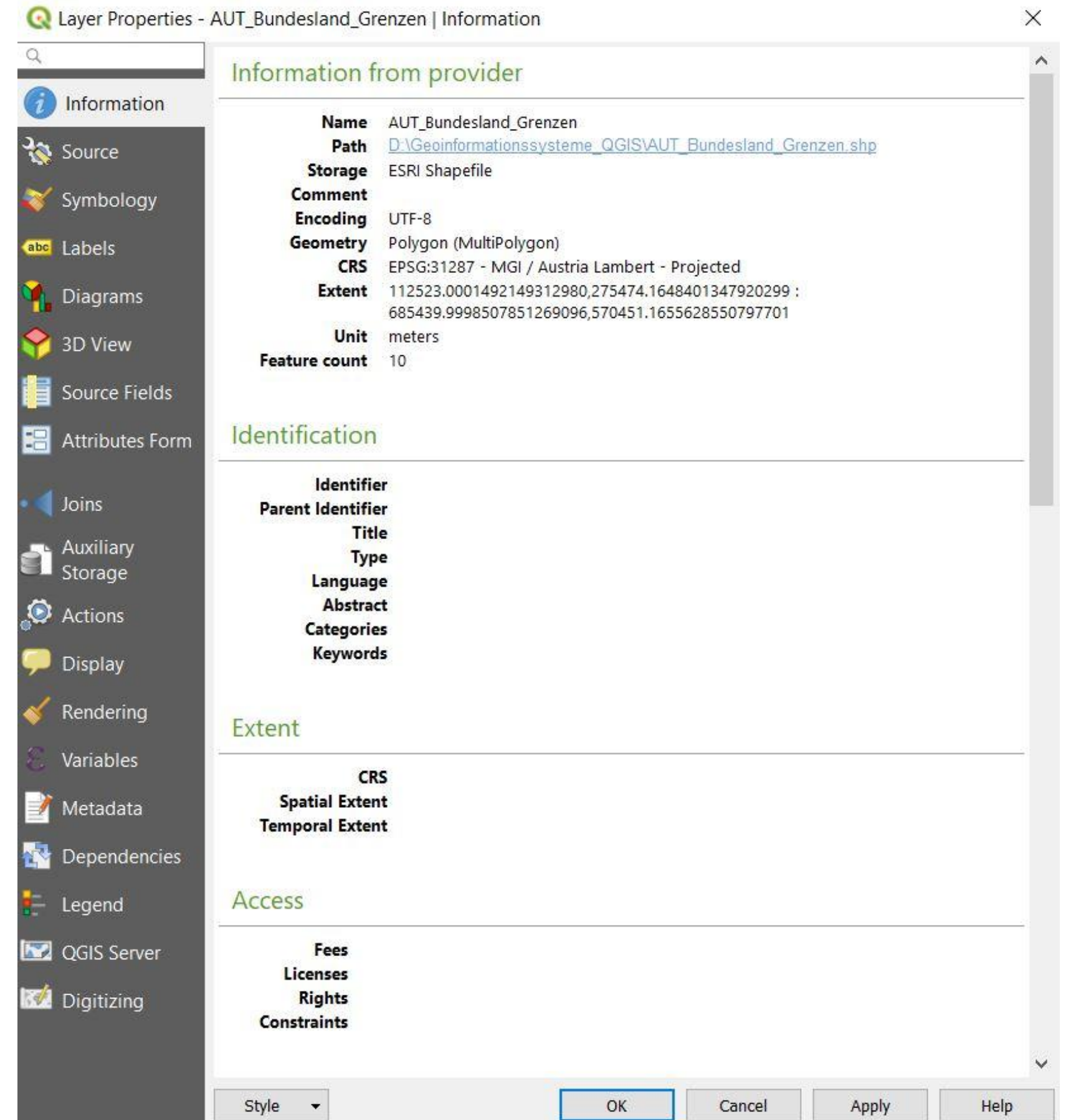
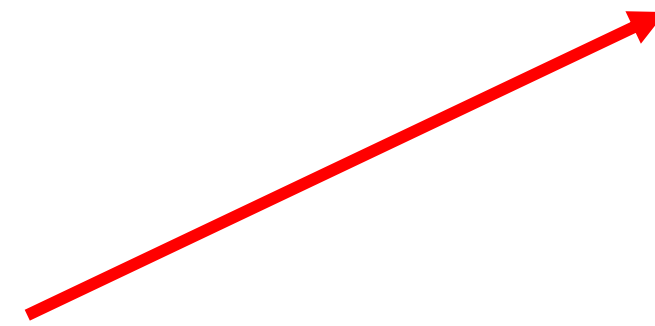
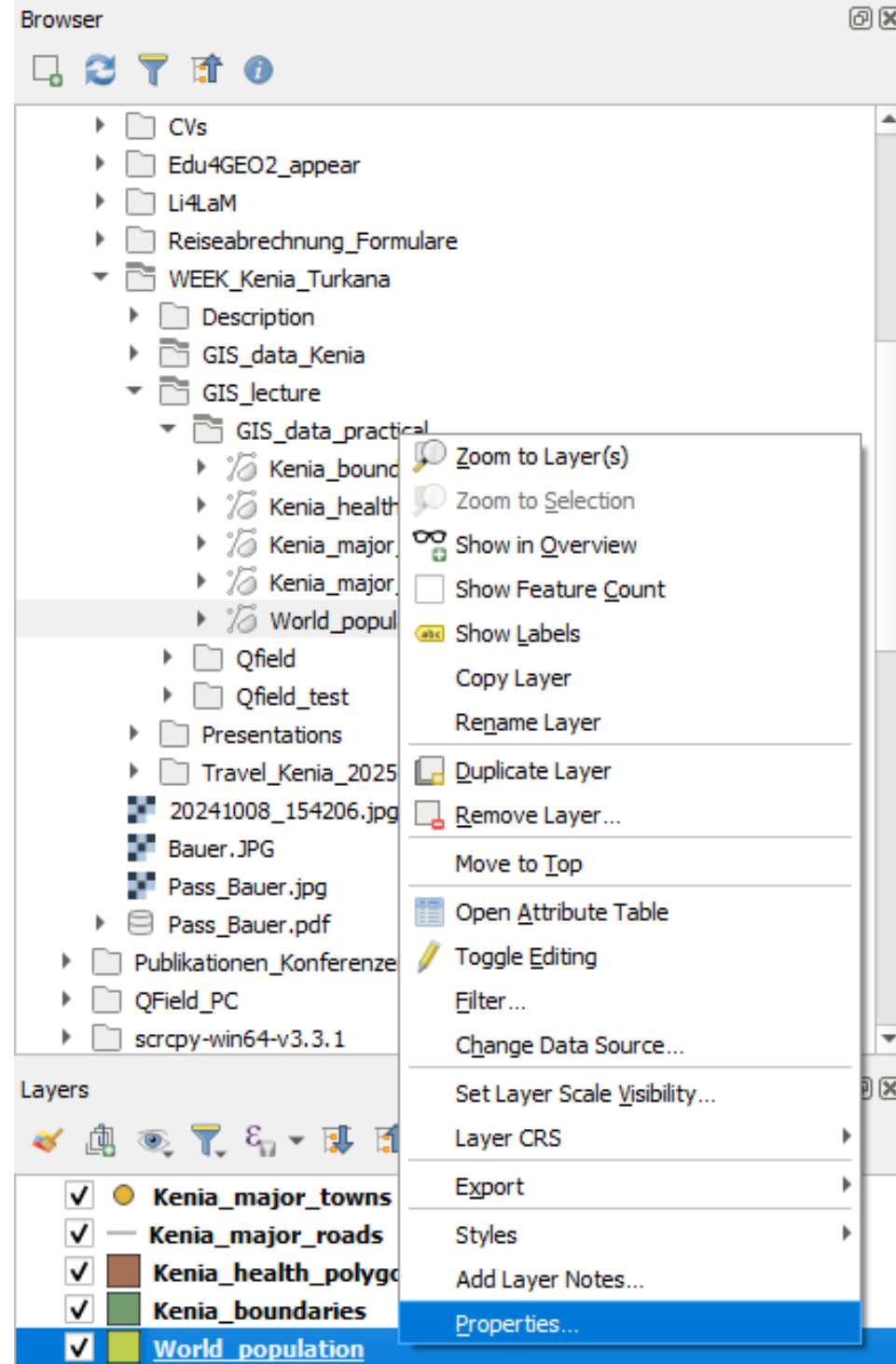
Right mouse-button on layer-name

The most important functions are:

- **Zoom to Layer:** important if data is not displayed or you have "lost your way" in the data. The system zooms to the entire extent of the selected layer.
- **Remove Layer:** the layer is deleted from the QGIS project. The record remains on disk!
- **Layer CRS:** the coordinate reference system can be defined for this layer.
- **Open Attribute Table:** beside the objects (geometry) there is always an attribute table behind it, where properties for the objects can be stored.
- **Toggle Editing:** if you want to modify the shape of objects or attributes or add new ones, you can switch the editing mode on and off with this command.
- **Export:** with this you can export all or only selected objects to a new data set (e.g. Shape file).
- **Filter:** restrict which objects should be displayed (you must then define a query).
- **Properties:** if you want to change the display type (symbols, labels, etc.), this is done via the properties of the layer.

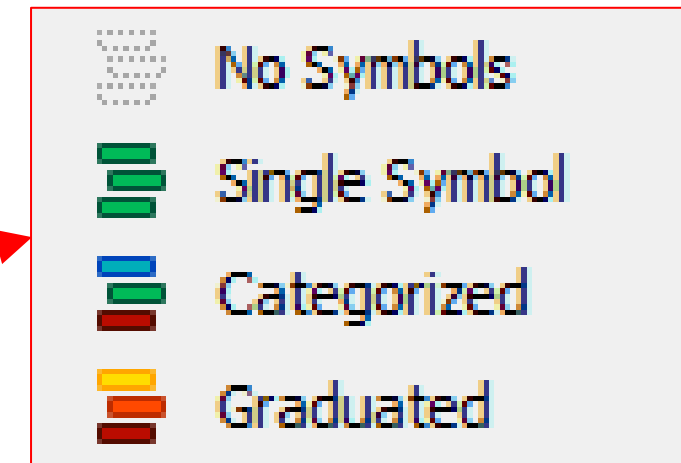
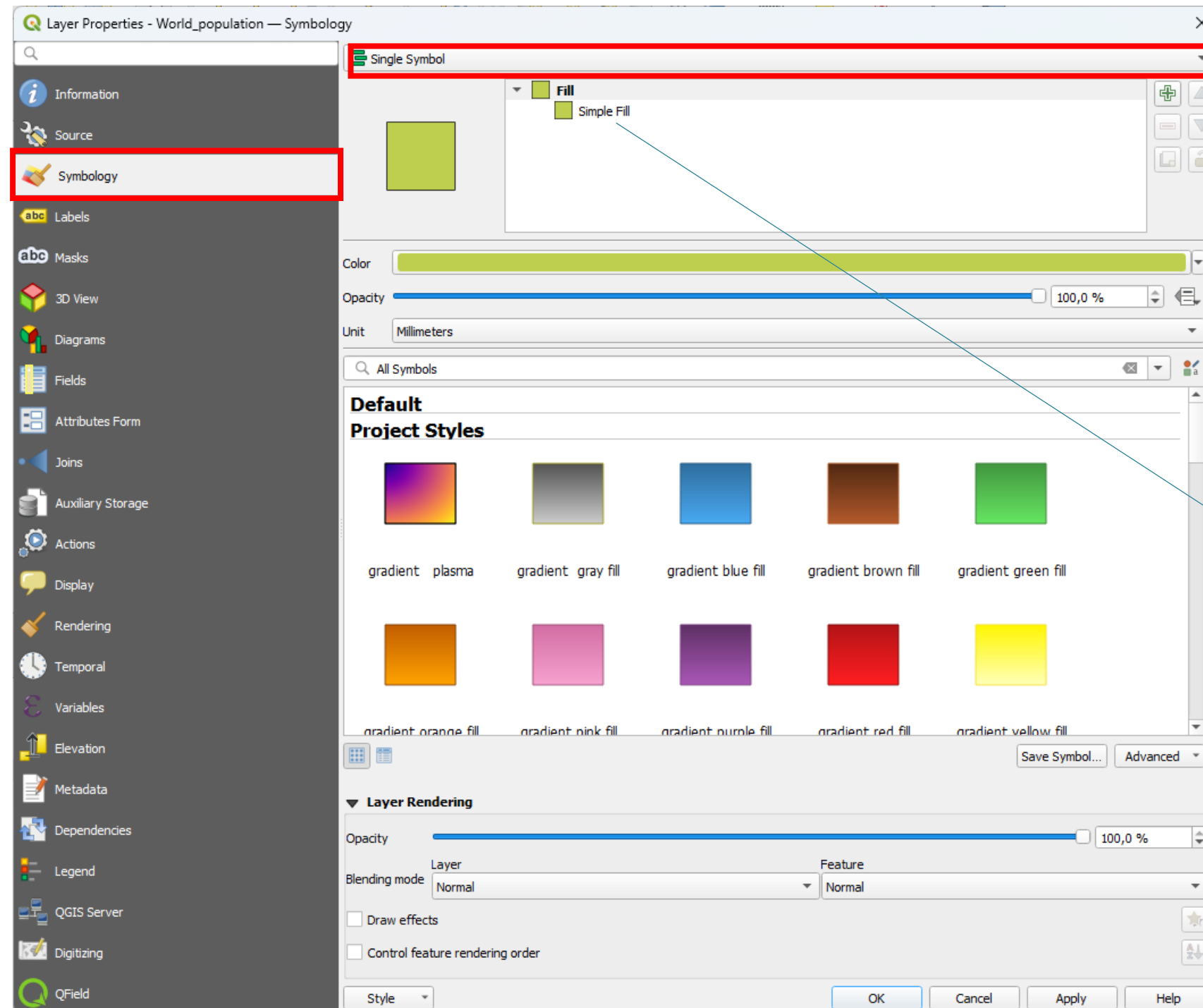
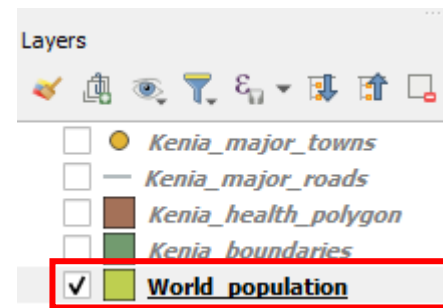
Displaying data

- **Properties for displaying layers**



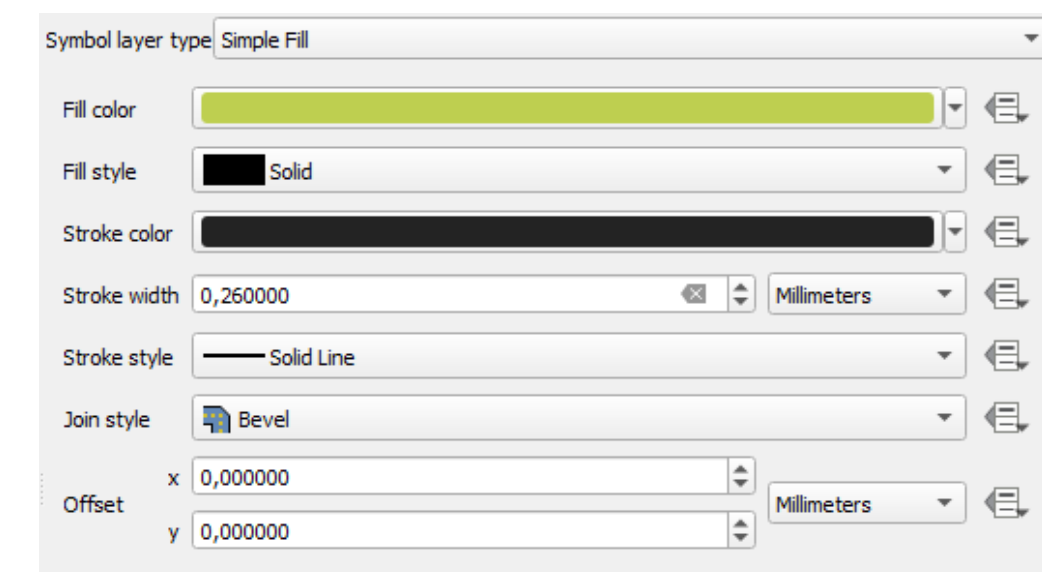
Displaying data

- Properties for displaying layers



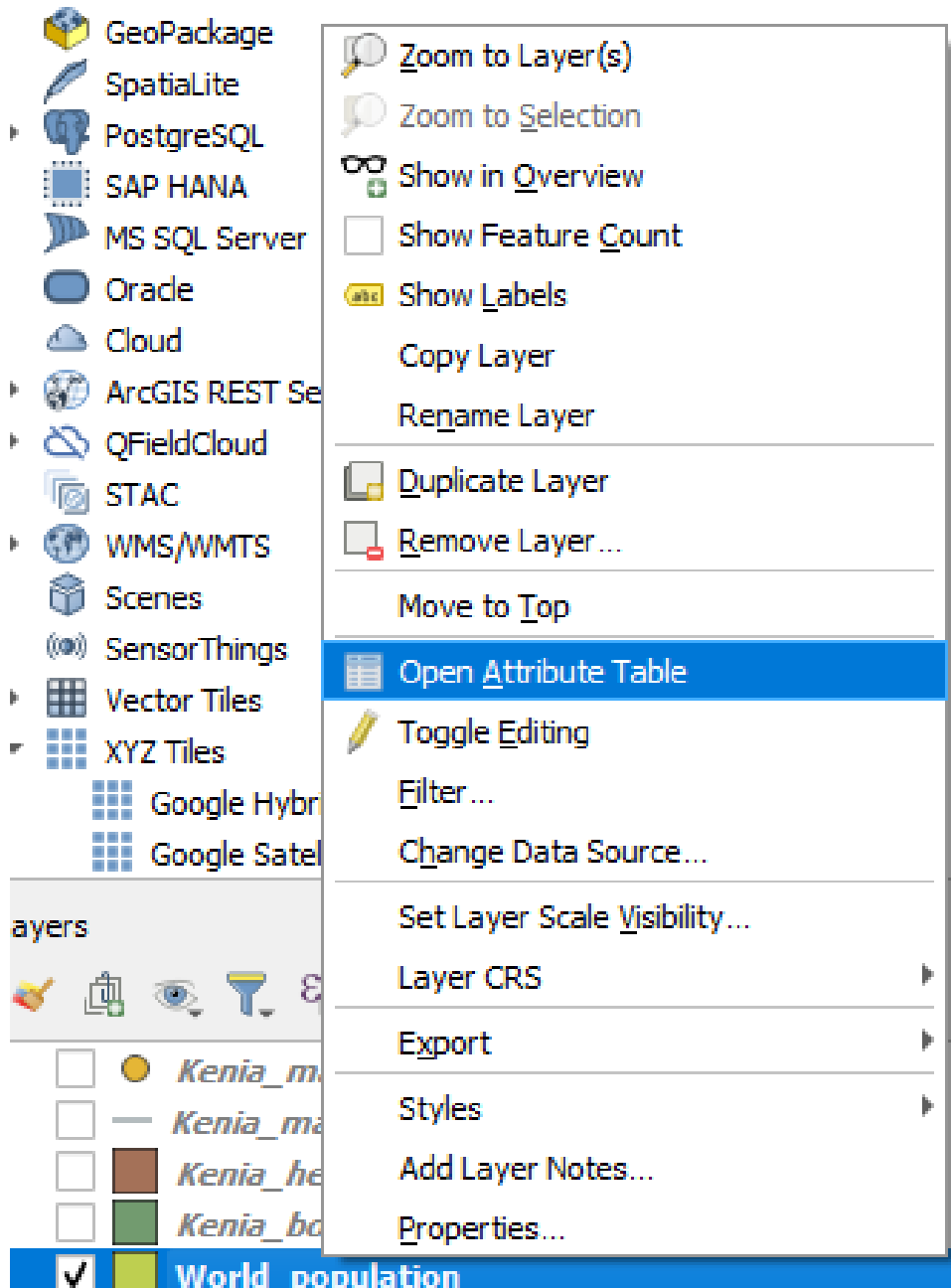
- Change colour
- Use pre-defined symbols
- Layer rendering: set opacity

- Simple Fill:



Displaying data

- **Properties for displaying layers: check attribute table!**



World_population — Features Total: 651, Filtered: 651, Selected: 0

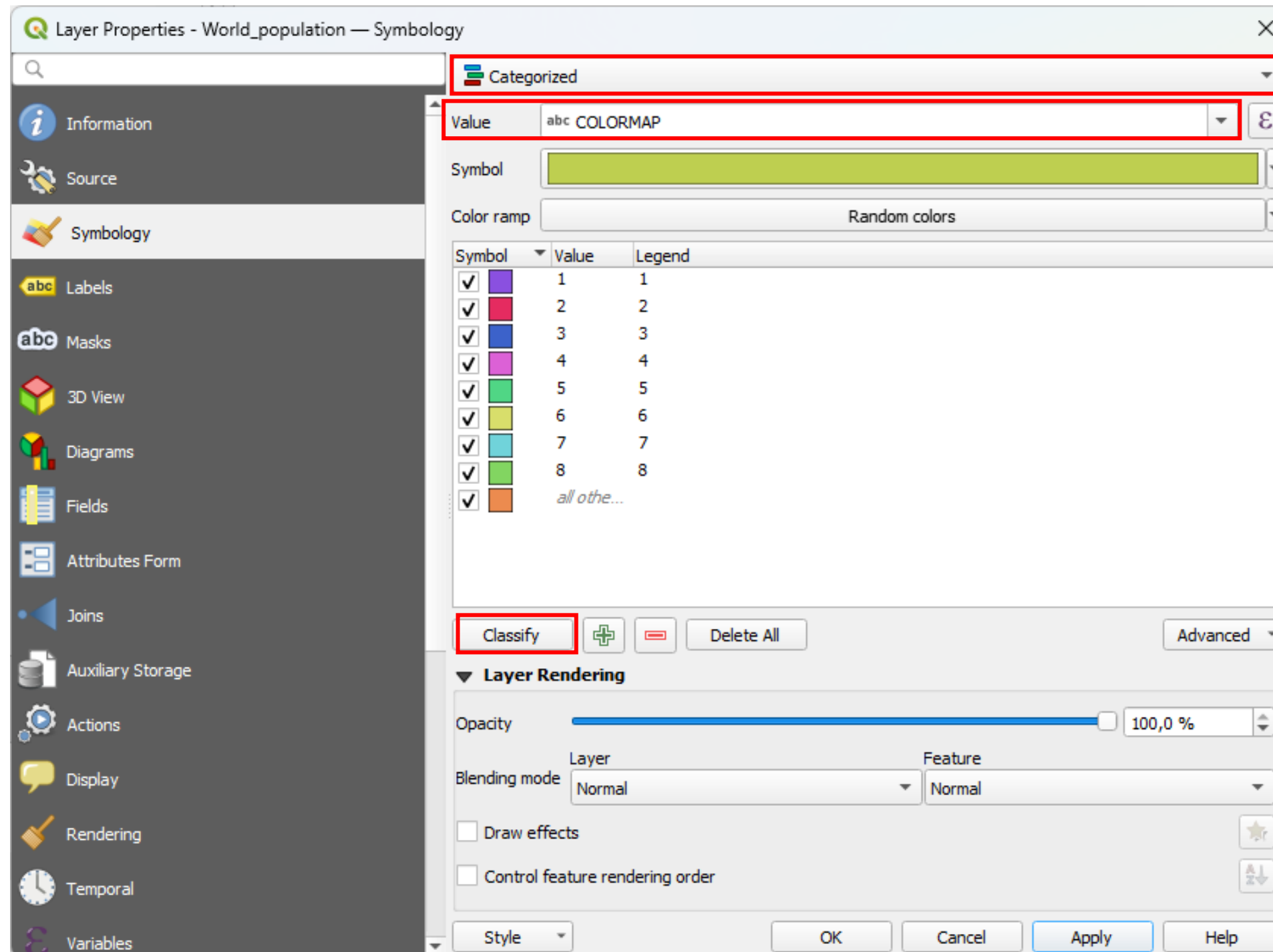
	FIPS_CNTRY	ISO_2DIGIT	ISO_3DIGIT	NAME	LONG_NAME	ICSHRTNA	LOCLNGNAM	CAPITAL	COUNTRYAFF	CONTINENT	LAND_TYPE	AND_RAN	COLORMAP	Shape_Leng	Shape_Area	ISO_NUMERI	WB_Country	
1	AQ	AS	ASM	American Samoa	Territory of American Samoa	NULL	NULL	Pago Pago	United States	Oceania	Very small island	1	2	0,26663863158	9,363915e-05	016	American Samoa	201
2	AQ	AS	ASM	American Samoa	Territory of American Samoa	NULL	NULL	Pago Pago	United States	Oceania	Small island	2	2	0,63552598343	0,00527502717	016	American Samoa	201
3	AQ	AS	ASM	American Samoa	Territory of American Samoa	NULL	NULL	Pago Pago	United States	Oceania	Primary land	5	2	1,18021144793	0,01143616192	016	American Samoa	201
4	AV	AI	AIA	Anguilla	Anguilla	NULL	NULL	The Valley	United Kingdom	North America	Primary land	5	6	0,03151833839	3,783284e-05	660	NULL	
5	AV	AI	AIA	Anguilla	Anguilla	NULL	NULL	The Valley	United Kingdom	North America	Very small island	1	6	0,11824602011	0,00010427369	660	NULL	
6	AV	AI	AIA	Anguilla	Anguilla	NULL	NULL	The Valley	United Kingdom	North America	Small island	2	6	0,83869869011	0,00696720987	660	NULL	
7	AY	AQ	ATA	Antarctica	Antarctica	NULL	NULL	NULL	NULL	Antarctica	Small island	2	7	91,03635537920	1,72737920091	010	NULL	
8	AY	AQ	ATA	Antarctica	Antarctica	NULL	NULL	NULL	NULL	Antarctica	Primary land	5	7	1292,697409630...	6074,572682310...	010	NULL	
9	AY	AQ	ATA	Antarctica	Antarctica	NULL	NULL	NULL	NULL	Antarctica	Large island	4	7	113,72276353500	26,21902577890	010	NULL	
10	AY	AQ	ATA	Antarctica	Antarctica	NULL	NULL	NULL	NULL	Antarctica	Medium island	3	7	123,27361516000	9,21628616797	010	NULL	
11	AC	AG	ATG	Antigua and Barbuda	Antigua and Barbuda	NULL	NULL	Saint John's	Antigua and Barbuda	North America	Small island	2	2	0,14708770578	0,0002675724	028	Antigua and Barbuda	556
12	AC	AG	ATG	Antigua and Barbuda	Antigua and Barbuda	NULL	NULL	Saint John's	Antigua and Barbuda	North America	Very small island	1	2	0,20735208407	0,00013511274	028	Antigua and Barbuda	556
13	AC	AG	ATG	Antigua and Barbuda	Antigua and Barbuda	NULL	NULL	Saint John's	Antigua and Barbuda	North America	Primary land	5	2	2,54038580607	0,03659631666	028	Antigua and Barbuda	556
14	AA	AW	ABW	Aruba	Aruba	NULL	NULL	Oranjestad	Netherlands	South America	Small island	2	1	0,69907195789	0,01512430372	533	Aruba	549
15	AS	AU	AUS	Australia	Commonwealth of Australia	NULL	NULL	Canberra	Australia	Australia	Medium island	3	4	35,39660802280	1,84772857567	036	Australia	102
16	AS	AU	AUS	Australia	Commonwealth of Australia	NULL	NULL	Canberra	Australia	Australia	Primary land	5	4	463,95883089100	692,45120282700	036	Australia	102
17	AS	AU	AUS	Australia	Commonwealth of Australia	NULL	NULL	Canberra	Australia	Australia	Very small island	1	4	46,47501387770	0,03952849648	036	Australia	102

Which information of the attribute table do you want to display?

→ Right mouse-button

Displaying data

- **Properties for displaying layers: Categorized**



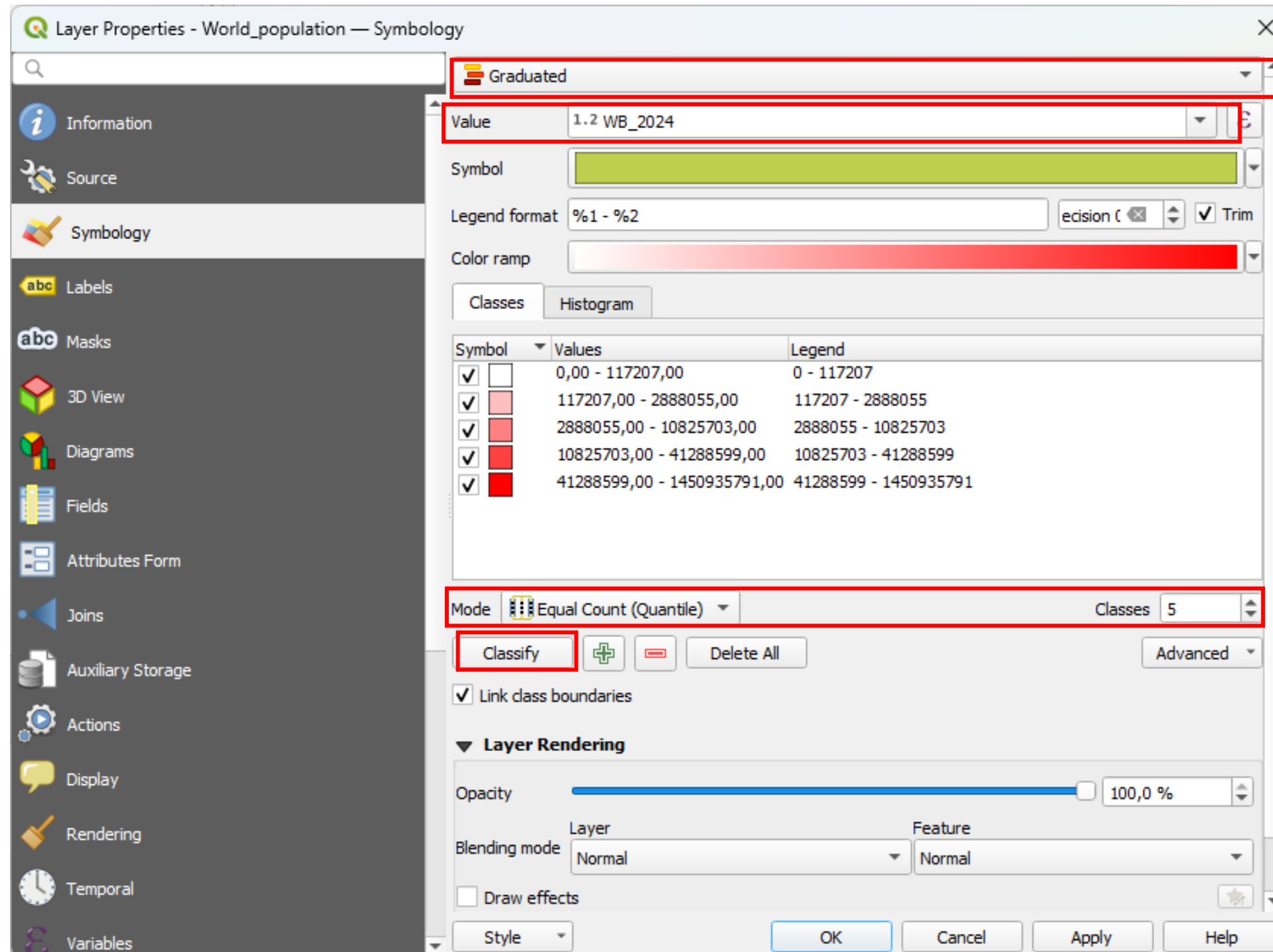
1. Refer to a column of the attribute table

→ *Must contain categories!*

2. Classify

Displaying data

- **Properties for displaying layers: Graduated**



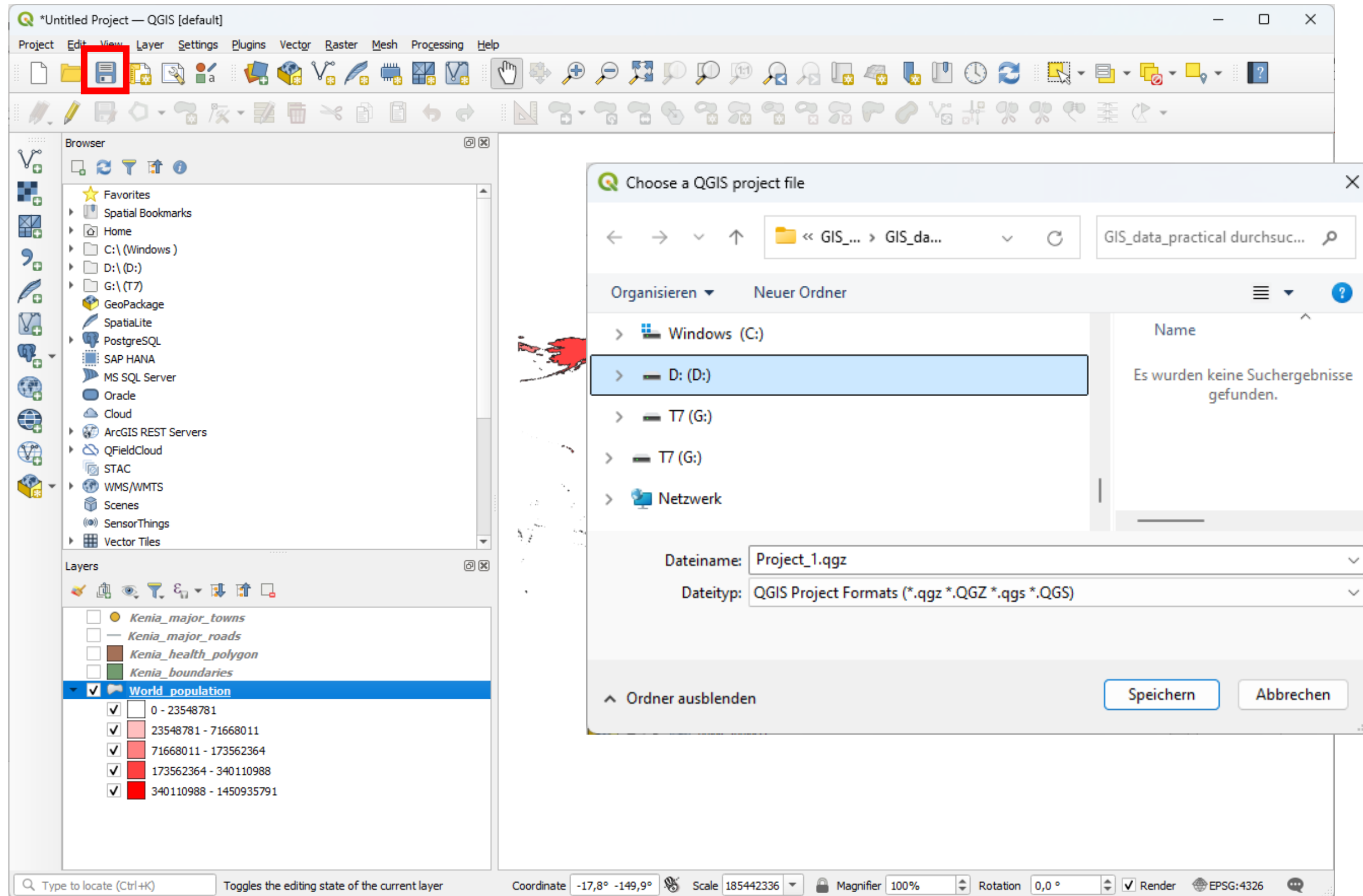
1. Refer to a column of the attribute table

→ used to represent quantitative data where a range of values is classified into different groups, and each group is assigned a unique symbol!

2. Choose Mode how to classify the data

3. Classify

Saving the project



→ Enter Name

→ Save

Day 1: Data management and coordinate systems

Create new data

Science for [life]

Data management

- **How to store geographic data in QGIS**

QGIS supports a variety of different data formats that are used to store geospatial data.

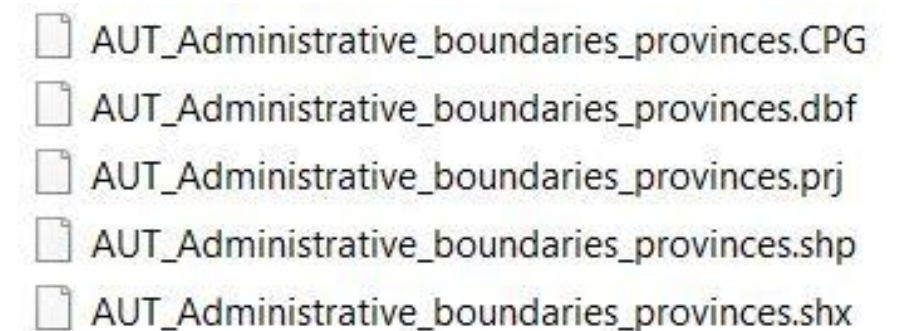
- **Geodatabase**

To store geospatial data in QGIS you can use spatial (open source) databases like SpatiaLite or GeoPackage, which can be created directly in QGIS.



- **Shape file**

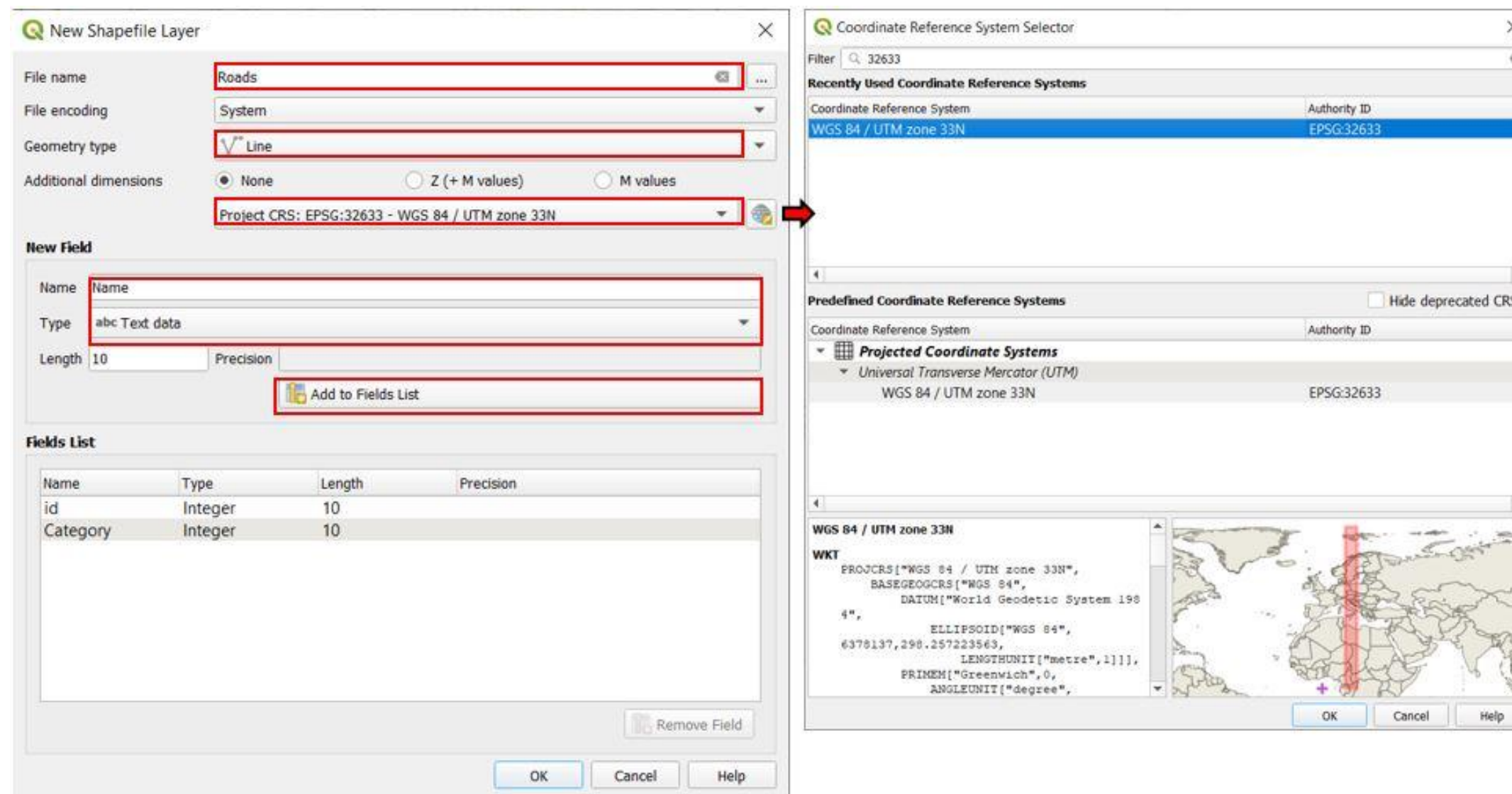
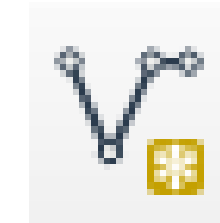
Simple, older format. It is used to store **point, line and polygon geometries** and the corresponding attribute information. This format can be read, created and edited by QGIS. The shape file consists of several individual files (e.g.: .dbf, .shp, .shx, .prj, .sbx) on the hard drive.



Definition of new layers

- **Create a new Shape-File**

- Manage Layer Toolbar or Layer - Create Layer - New Shapefile Layer.

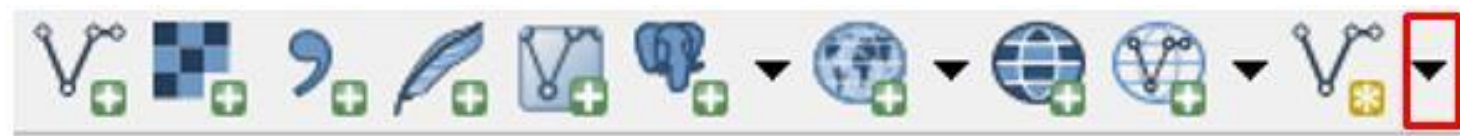
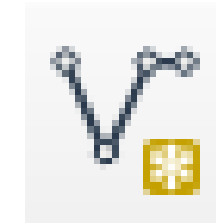


1. Name and location
2. Geometry type: point, line or polygon
3. Choose coordinate reference system (!)
4. Add columns („fields“) to the attribute table → information to be collected with the objects

Definition of new layers

- **Create a new GeoPackage-Database**

- Manage Layer Toolbar or Layer - Create Layer - New GeoPackage Layer.



New GeoPackage Layer

Database:

Table name:

Geometry type:

Include Z dimension Include M values

Project CRS: EPSG:32636 - WGS 84 / UTM zone 36N

New Field

Name:

Type:

Maximum length:

Fields List

Name	Type	Length
Attribut_1	integer	
Attribut_2	real	
Attribut_3	text	
Photo	text	
Date	date	

1. Specify location/create database
2. Name
3. Geometry type: point, line or polygon
4. Choose coordinate reference system (!)
5. Add columns („fields“) to the attribute table → information to be collected with the objects

Adding layers to existing database:

New GeoPackage Layer

Database:

Table name:

Geometry type:

Include Z dimension Include M values

Project CRS: EPSG:32636 - WGS 84 / UTM zone 36N

New Field

Name:

Type:

Maximum length:

Fields List

Name	Type	Length
Attbute_1	integer	

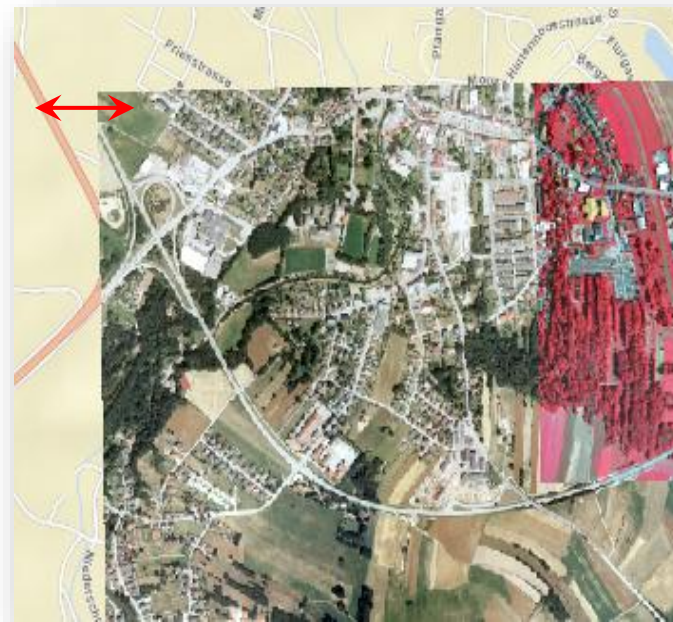
New GeoPackage Layer

The file already exists. Do you want to overwrite the existing file with a new database or add a new layer to it?

Coordinate reference system (CRS)

Challenges in GIS

- Positioning of geodata for analysis and visualization

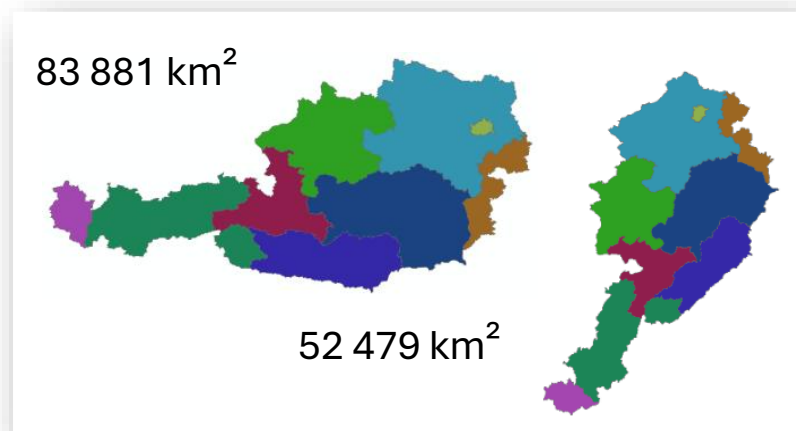


???

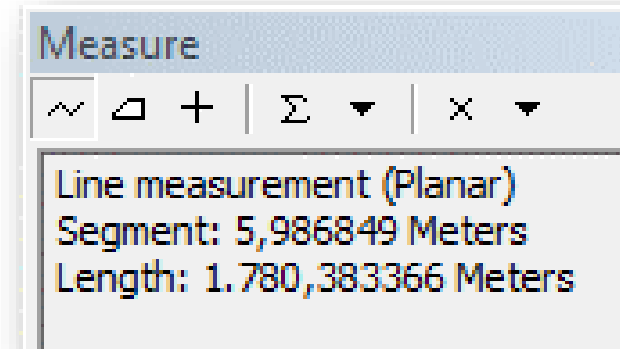
- Measuring distances



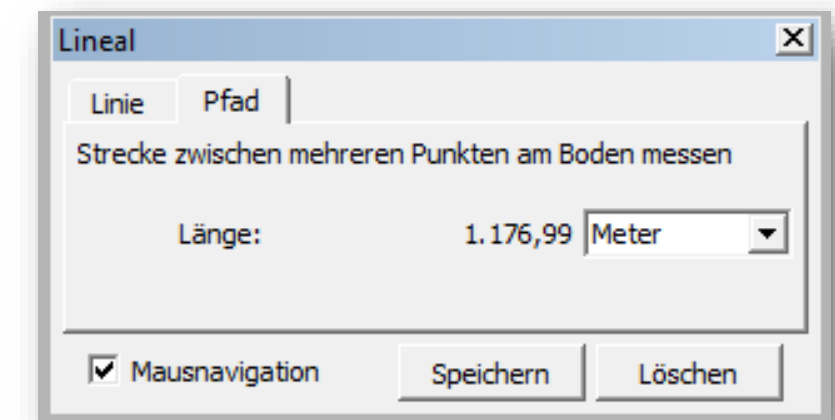
- Measuring area

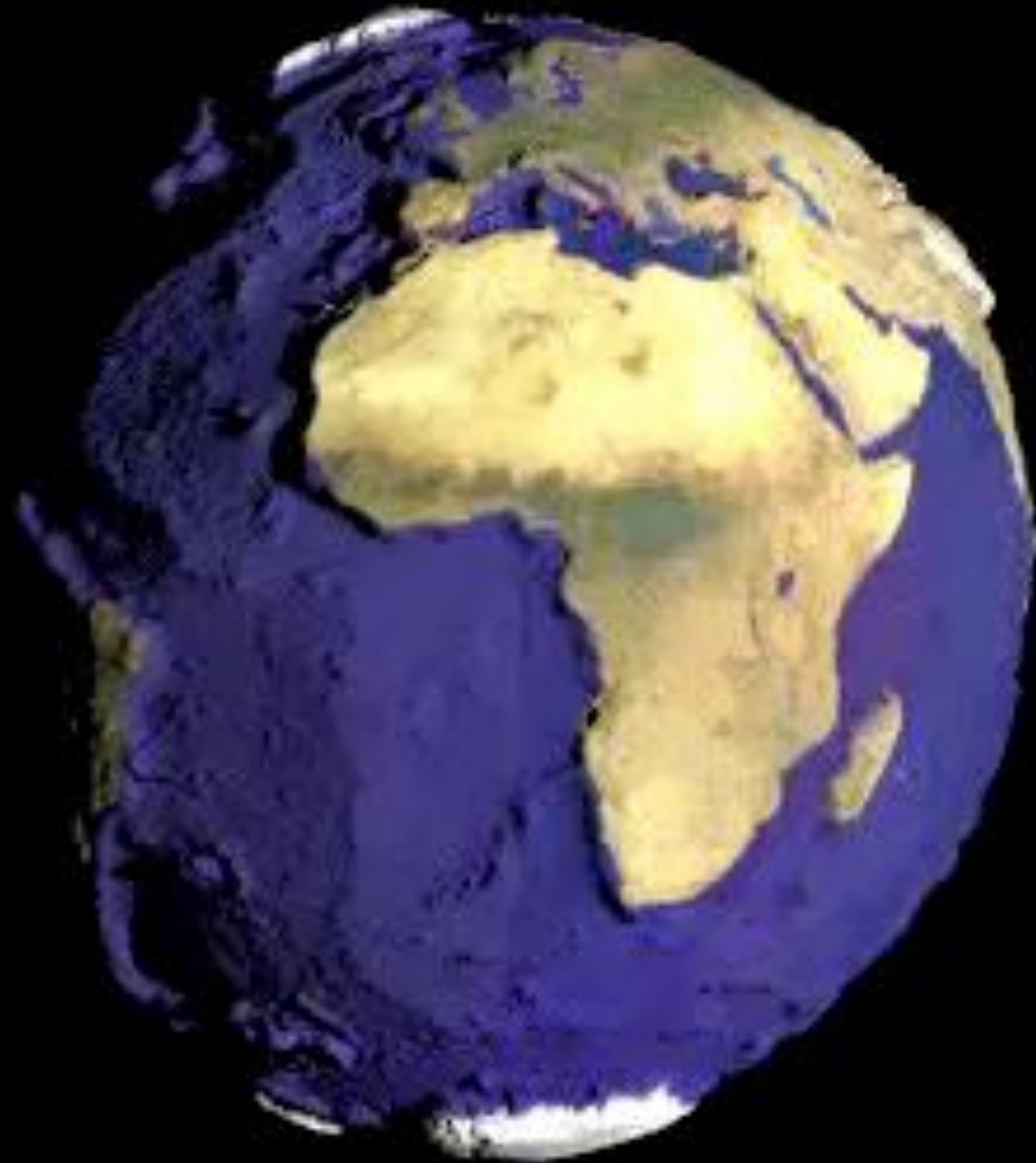


GIS

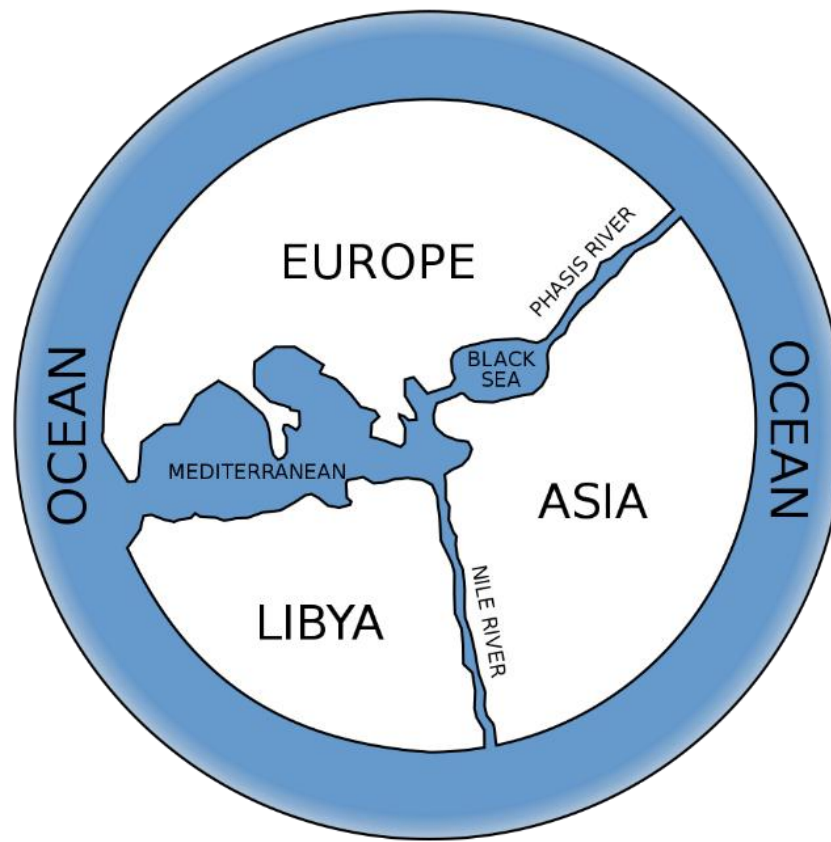


Google Earth





The Shape of the Earth



The Dream

“The Earth is a disc”



The Ideal

“The Earth is a sphere”



The Reality

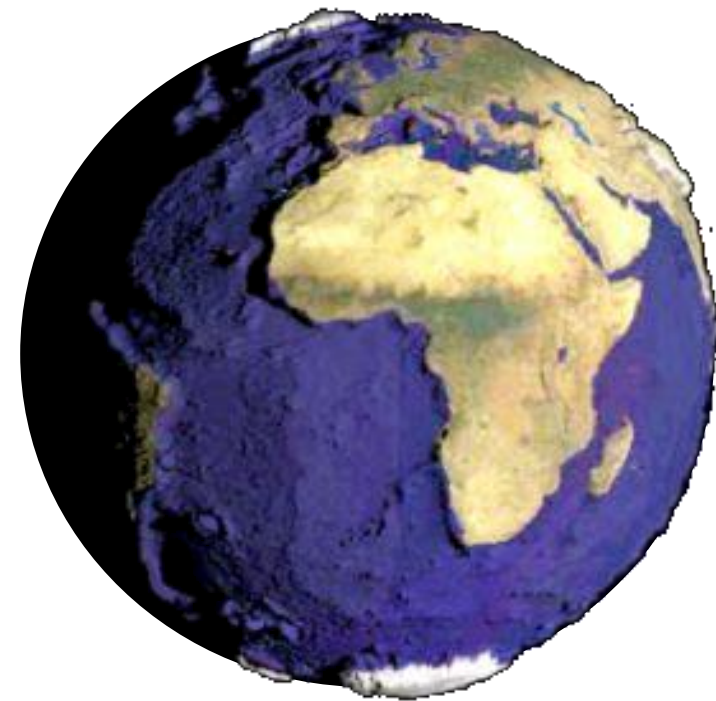
The surface of the Earth cannot be described neither physically nor mathematically

How to derive a 2D map?



https://www.esri.com/arcgis-blog/products/arcgis-pro/mapping/gcs_vs_pcs/

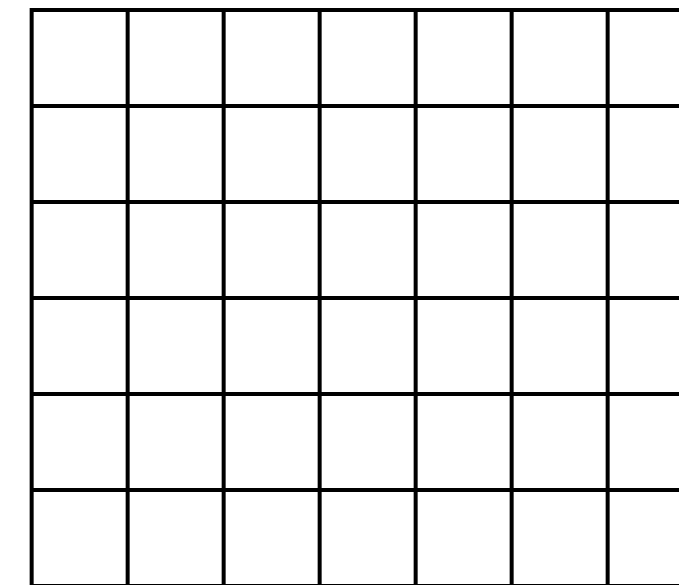
Workflow to the 2D map



Real earth figure

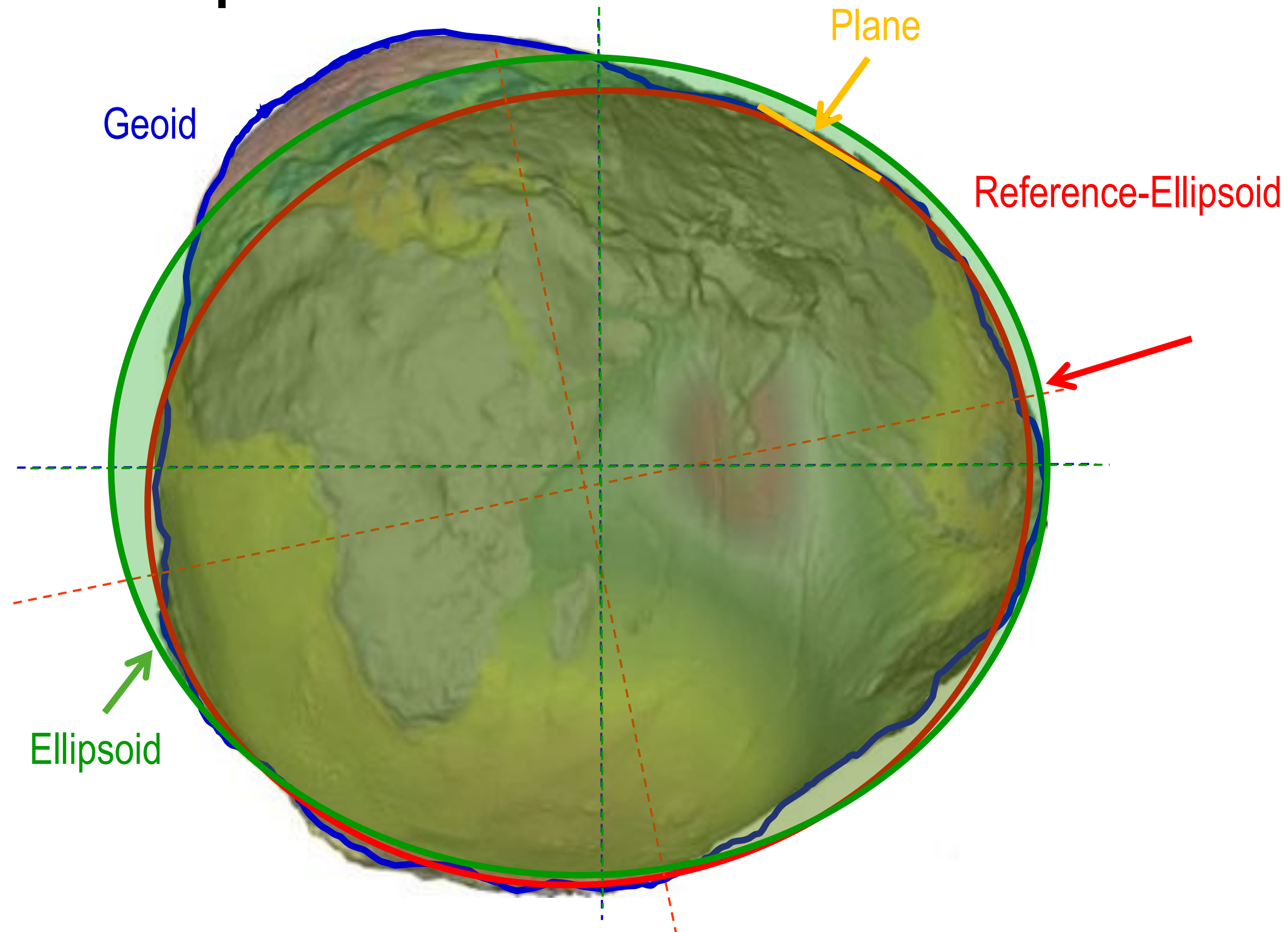


**Mathematical-
geometric
reference system**



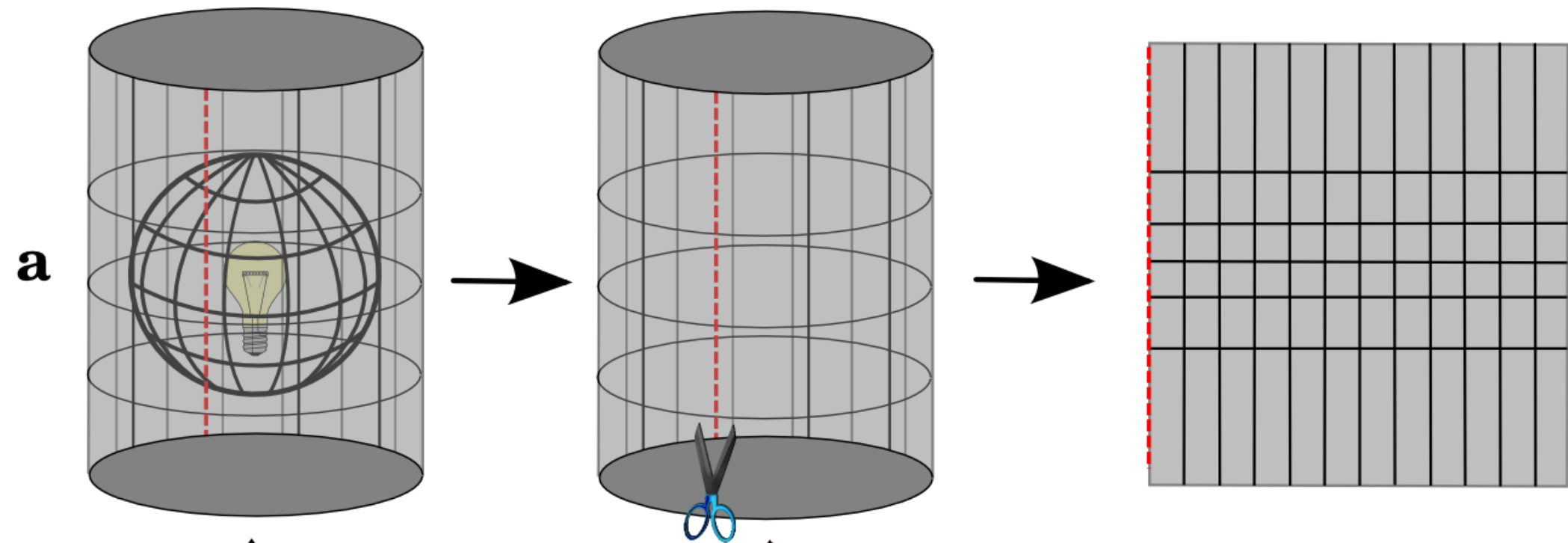
Map
Coordinates in a specific
coordinate system

Mathematical representation of Earth

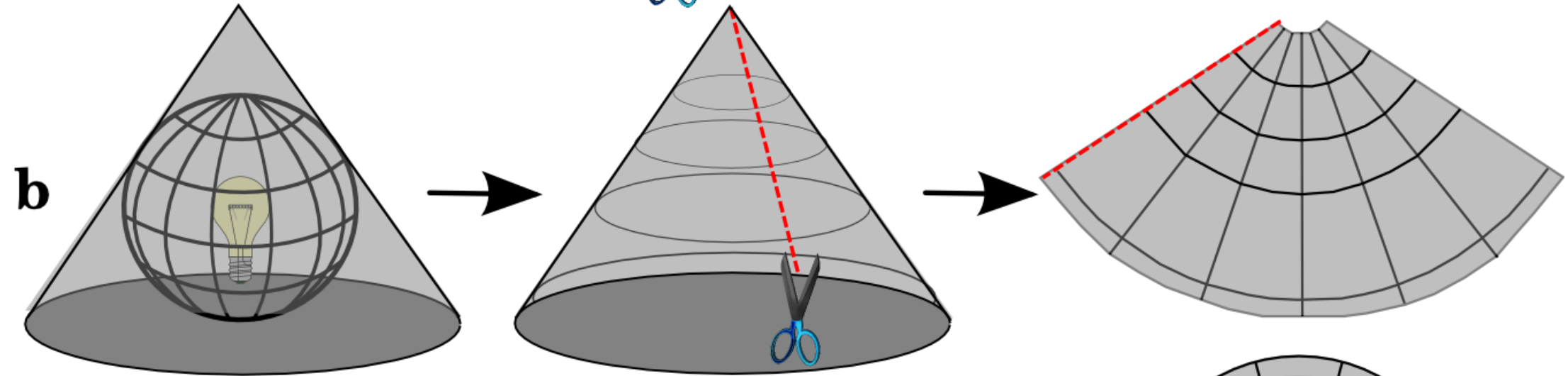


Map projections

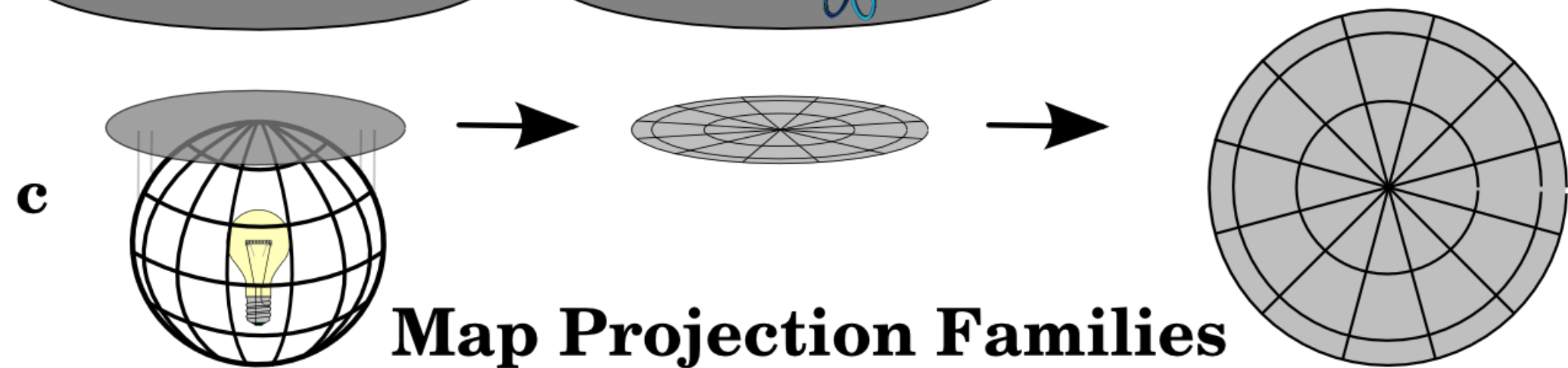
a. Cylindrical



b. Conical



c. Planar



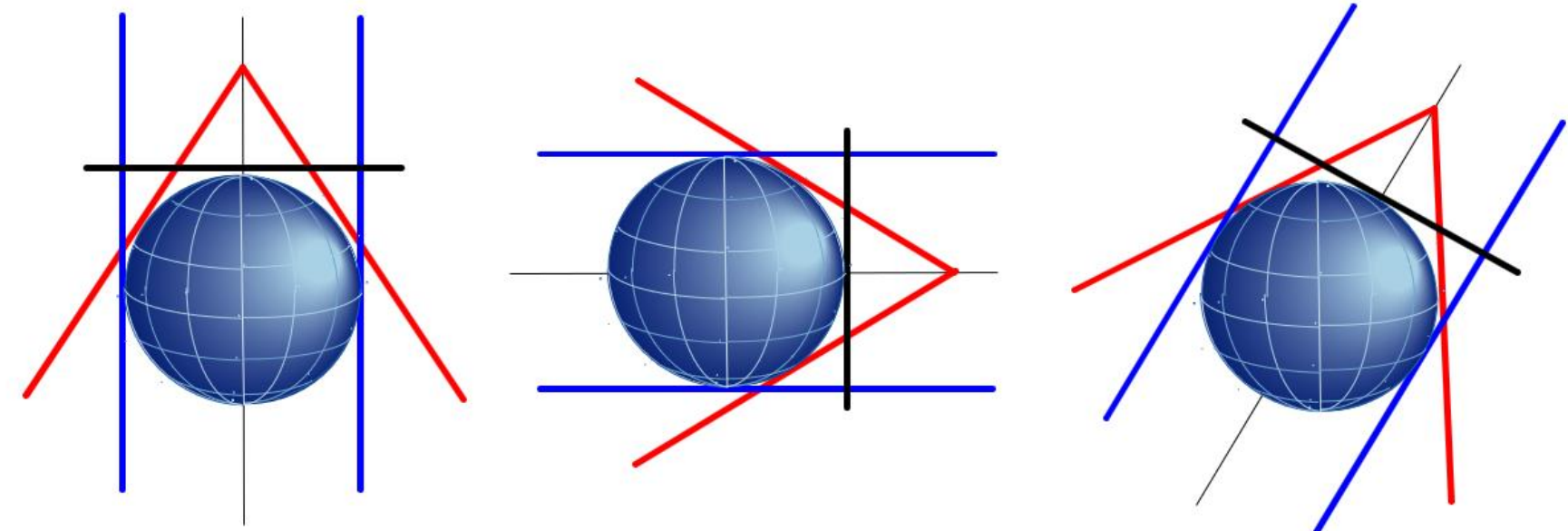
Map Projection Families

Characterisation of map projections

- **Distortions**

Map projections can be classified based on which properties they maintain. Since it's impossible to preserve all geometric properties when projecting the Earth's surface onto a plane, projections typically optimize one or more of the following properties:

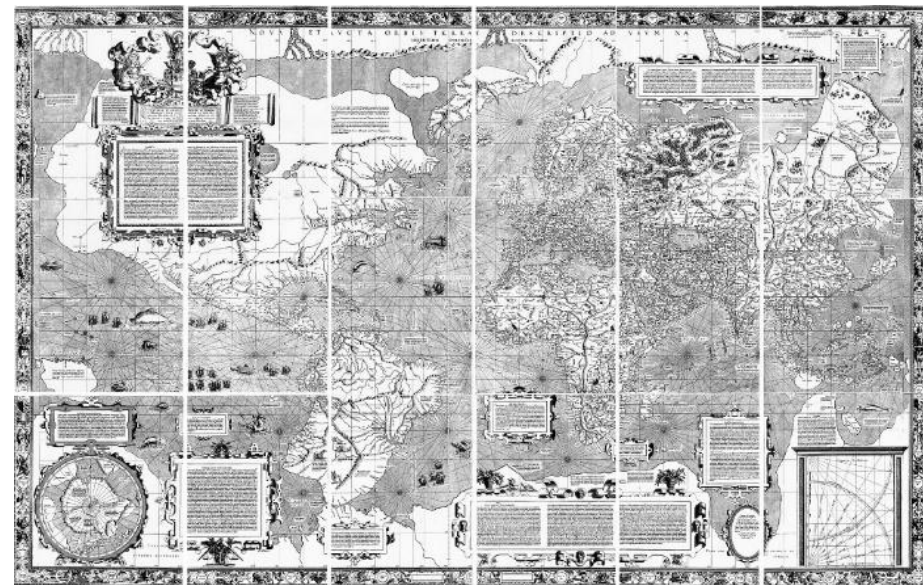
- **Conformal projections**
- **Equal-area (equivalent) projections**
- **Equidistant projections**



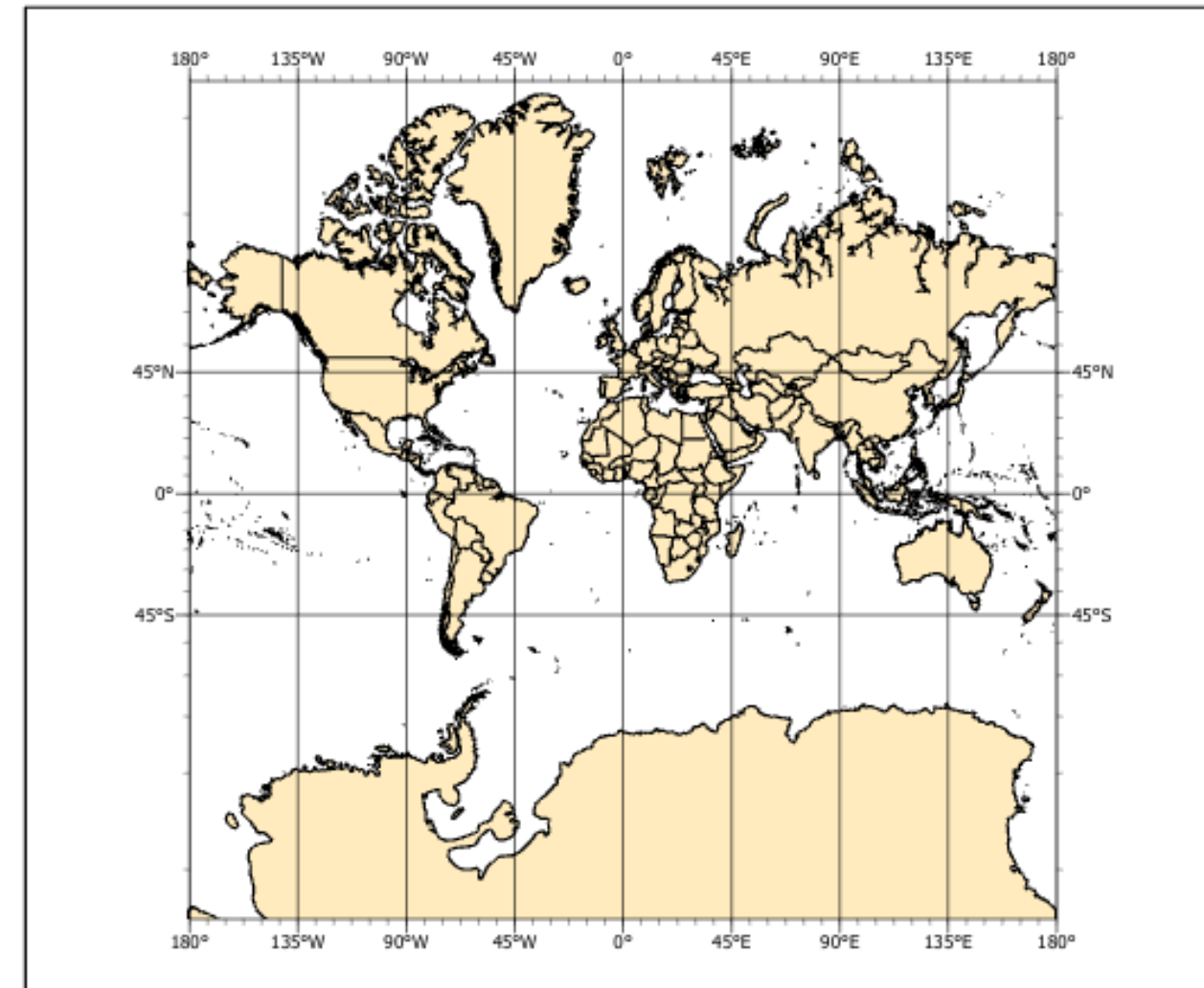
Characterisation of map projections

■ Conformal Projections:

- **What is preserved:** Angles (Shape)
- **Distortion:** Area and distance are distorted.
- **Example: Mercator Projection** (used in navigation because it preserves bearings).
- **Application:** Ideal for applications like navigation or aeronautical charts where maintaining angular relationships is critical.

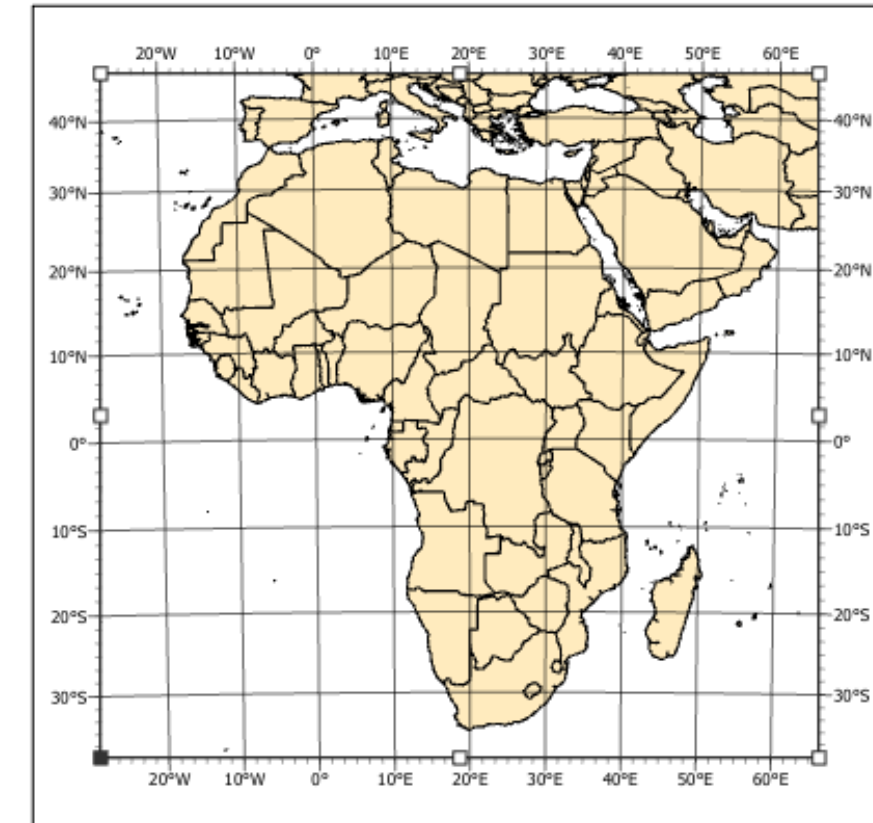


Gerhard Mercator - Basel copy of the 1569 world map photographed by Wilhelm Krucken.
https://commons.wikimedia.org/wiki/File:Mercator_1569_world_map_composite.jpg

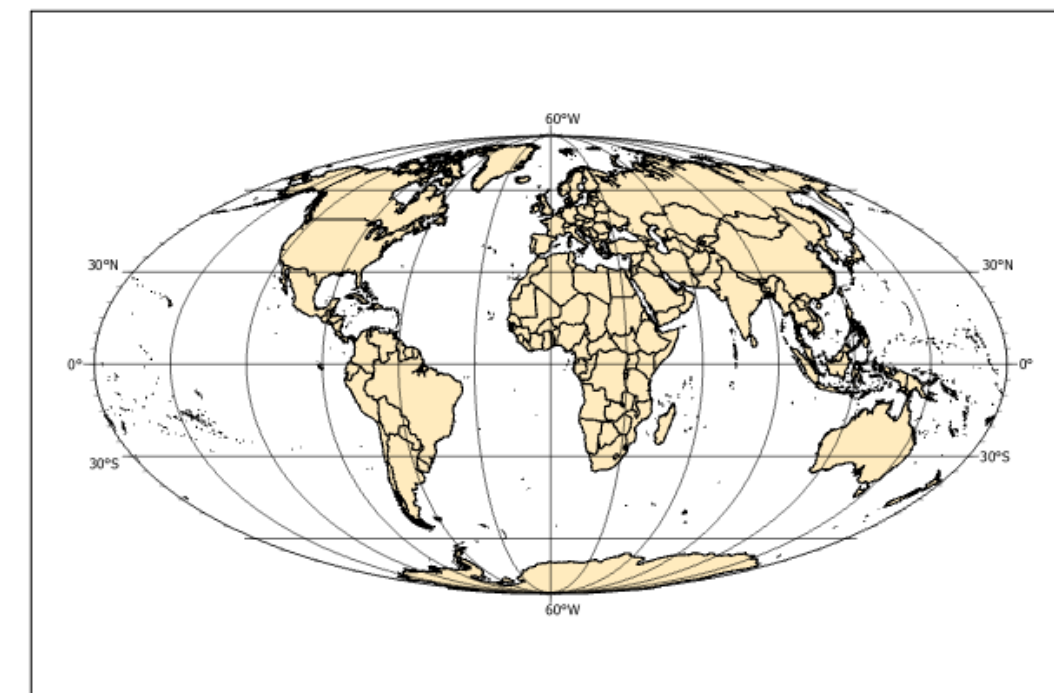


Characterisation of map projections

- **Equal-Area (Equivalent) Projections:**
 - **What is preserved:** Area is accurately represented across the map.
 - **Distortion:** Shape, especially near the poles or at the edges of the map, is distorted.
 - **Example:** Albers Equal-Area Conic Projection, Mollweide Projection.
 - **Application:** Used when the accurate comparison of areas (e.g., population distribution, land use) is needed.



Albers Equal Area Conic

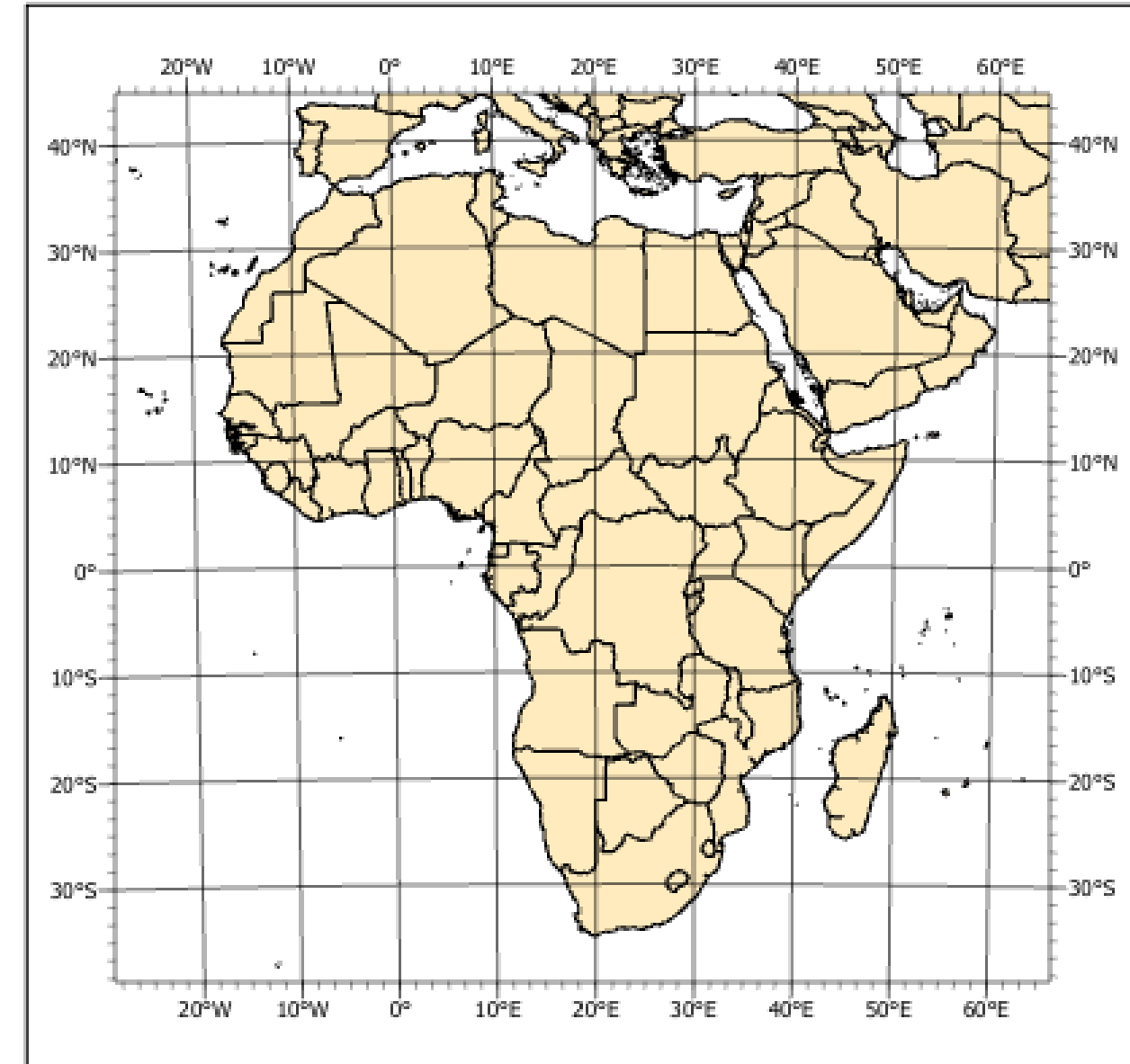


Mollweide

Characterisation of map projections

▪ Equidistant projections:

- **What is preserved:** Distances are preserved along certain lines (often along a central meridian or from a central point).
- **Distortion:** Areas and shapes may be distorted.
- **Example:** Azimuthal Equidistant Projection.
- **Application:** useful for applications like seismic mapping, or radio wave propagation, where maintaining distance accuracy from a point is important.



Equidistant Conic

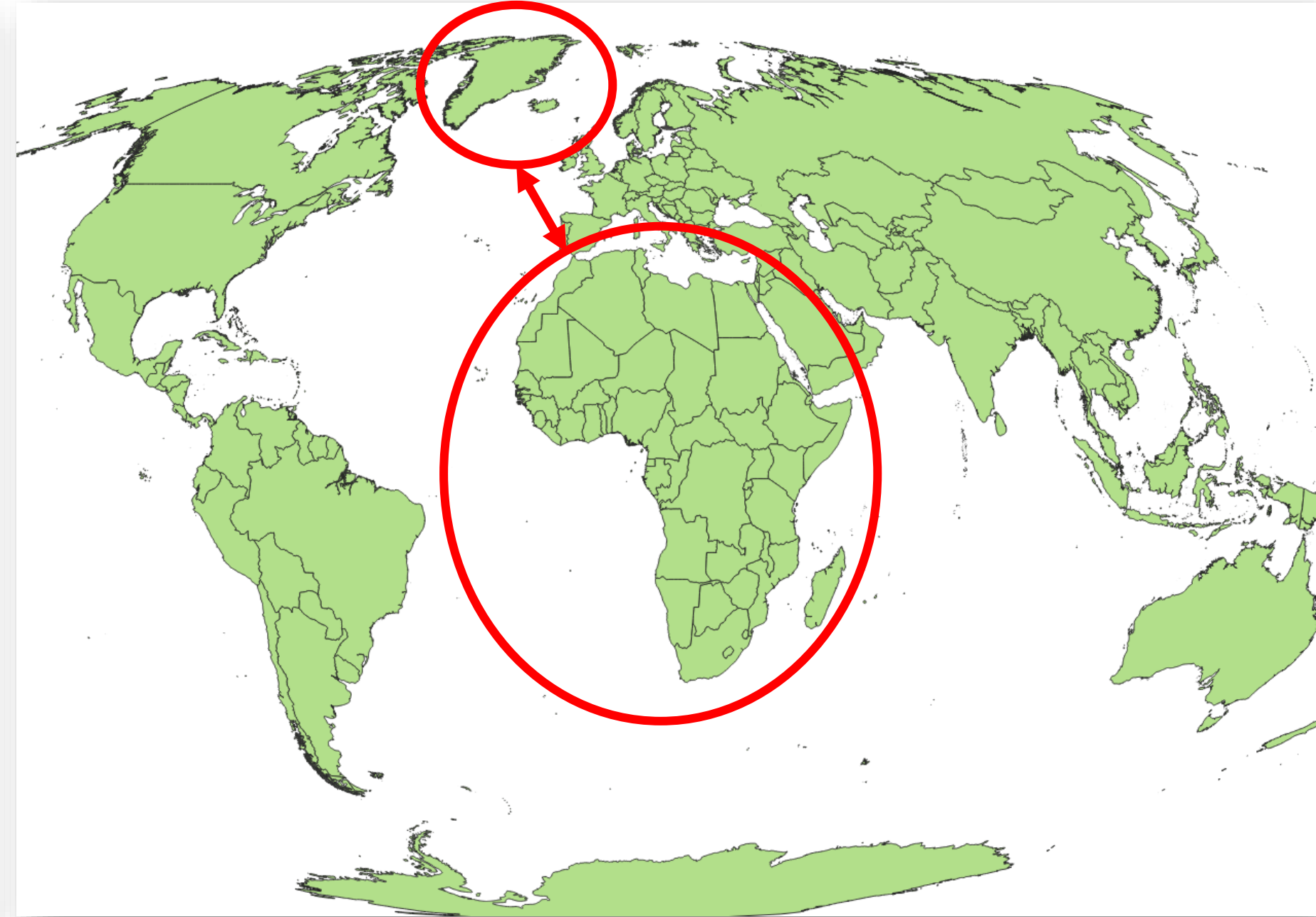
Characterisation of map projections

- Example for distortions

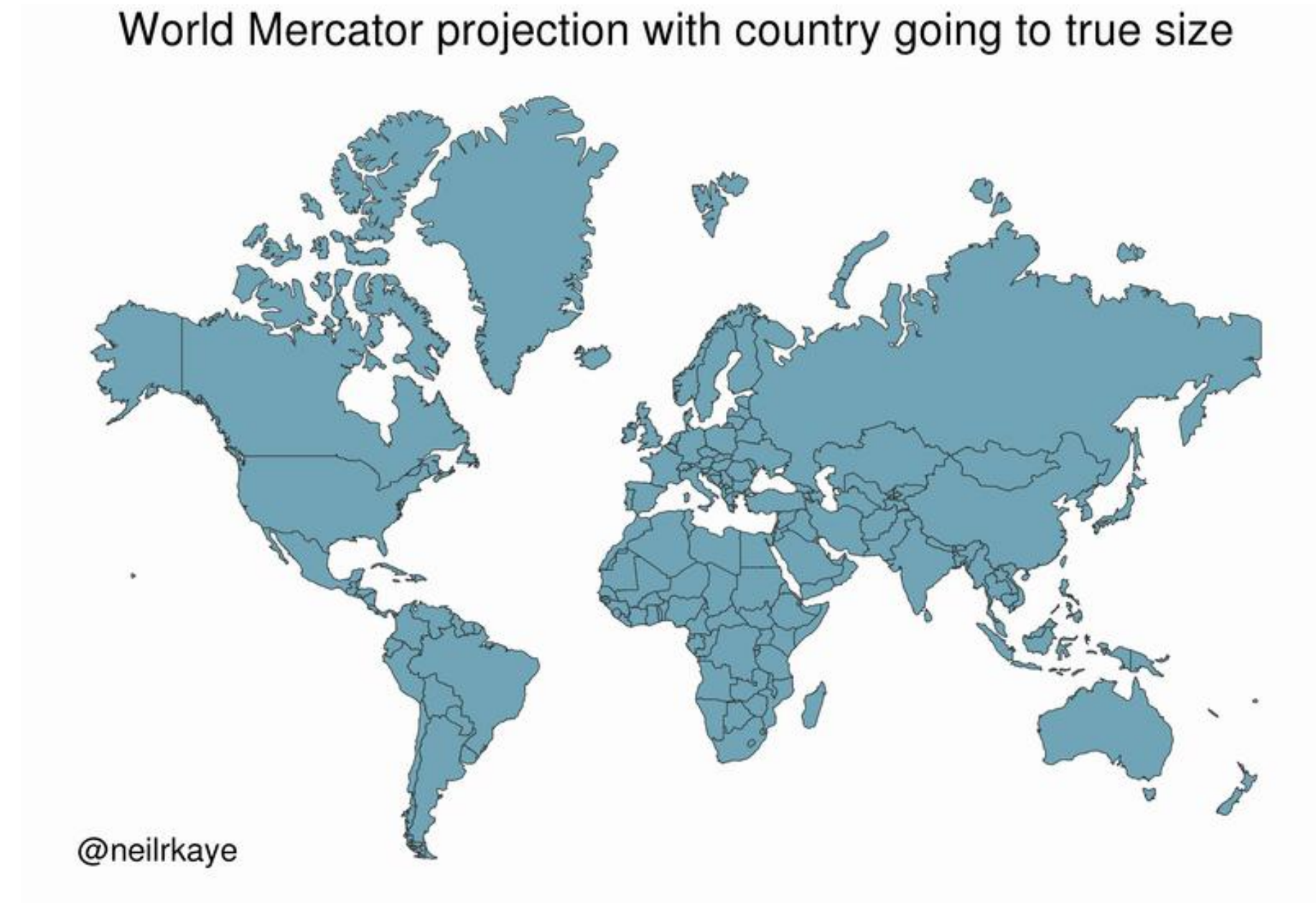
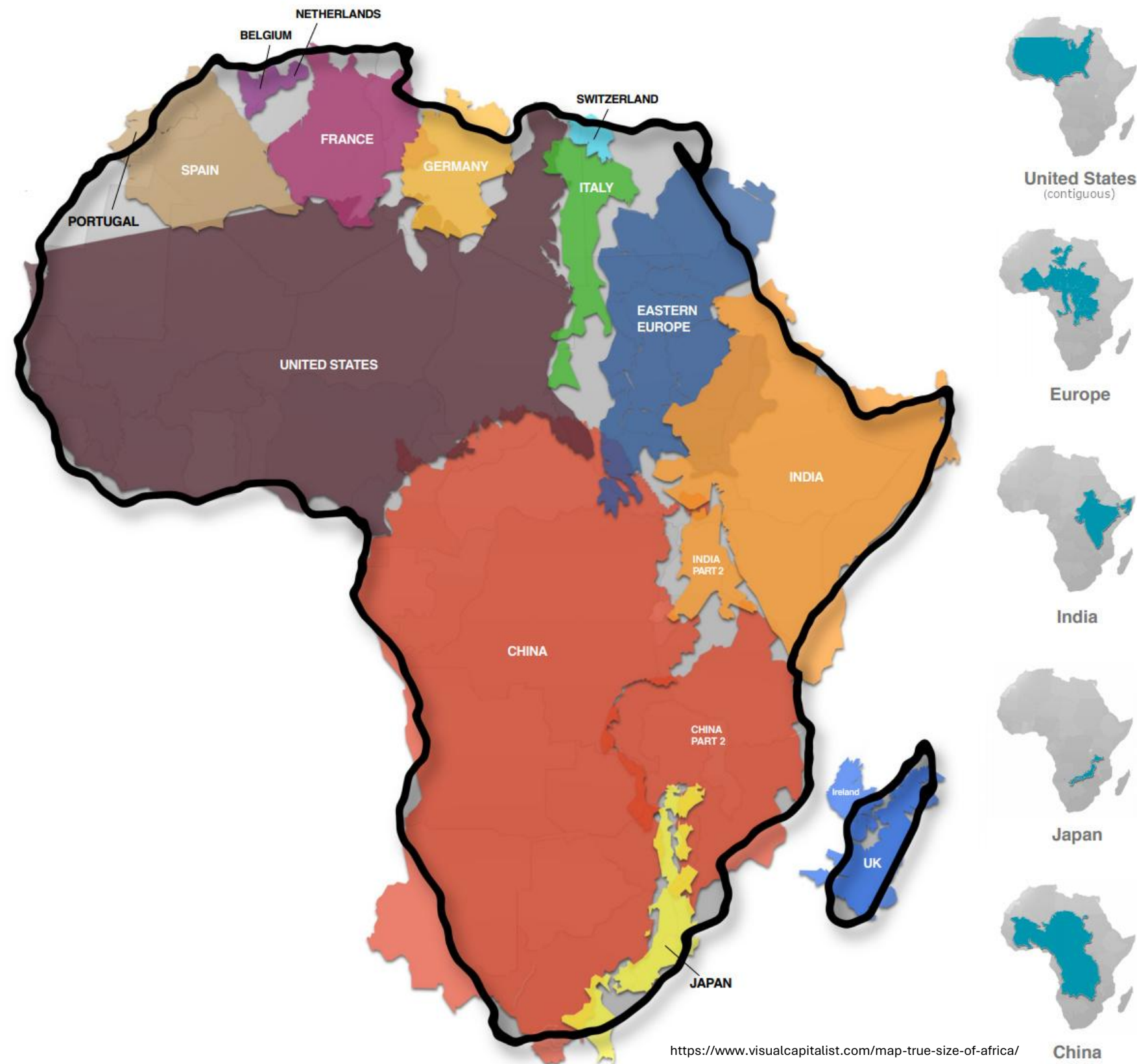
World Mercator



World Mollweide



Characterisation of map projections



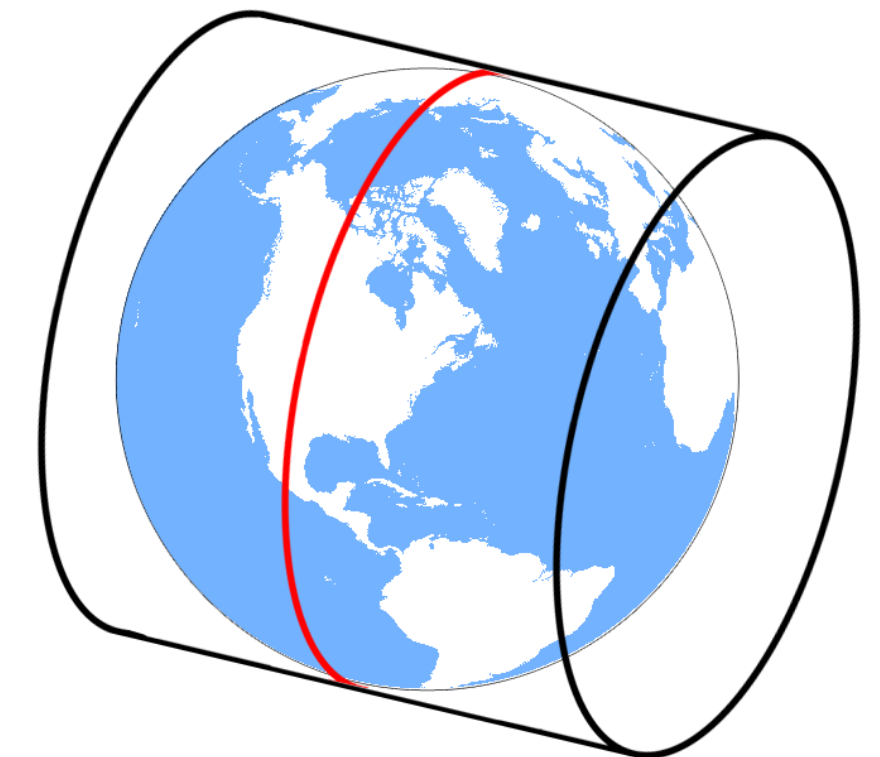
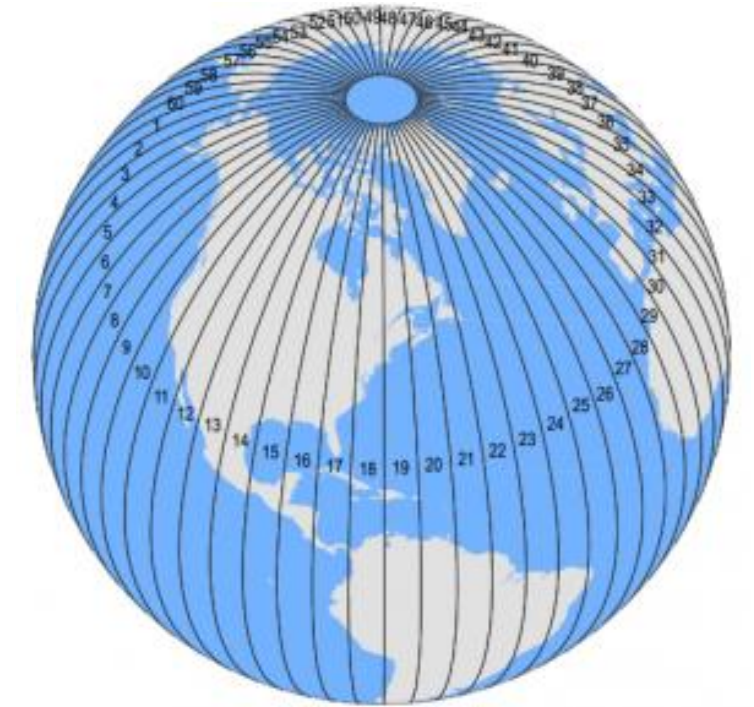
Universal Transverse Mercator - UTM

The **Universal Transverse Mercator (UTM)** system is a global map projection that divides the Earth into a series of 60 zones, each 6 degrees of longitude wide.

In many cases it is based on the **WGS84 datum**.

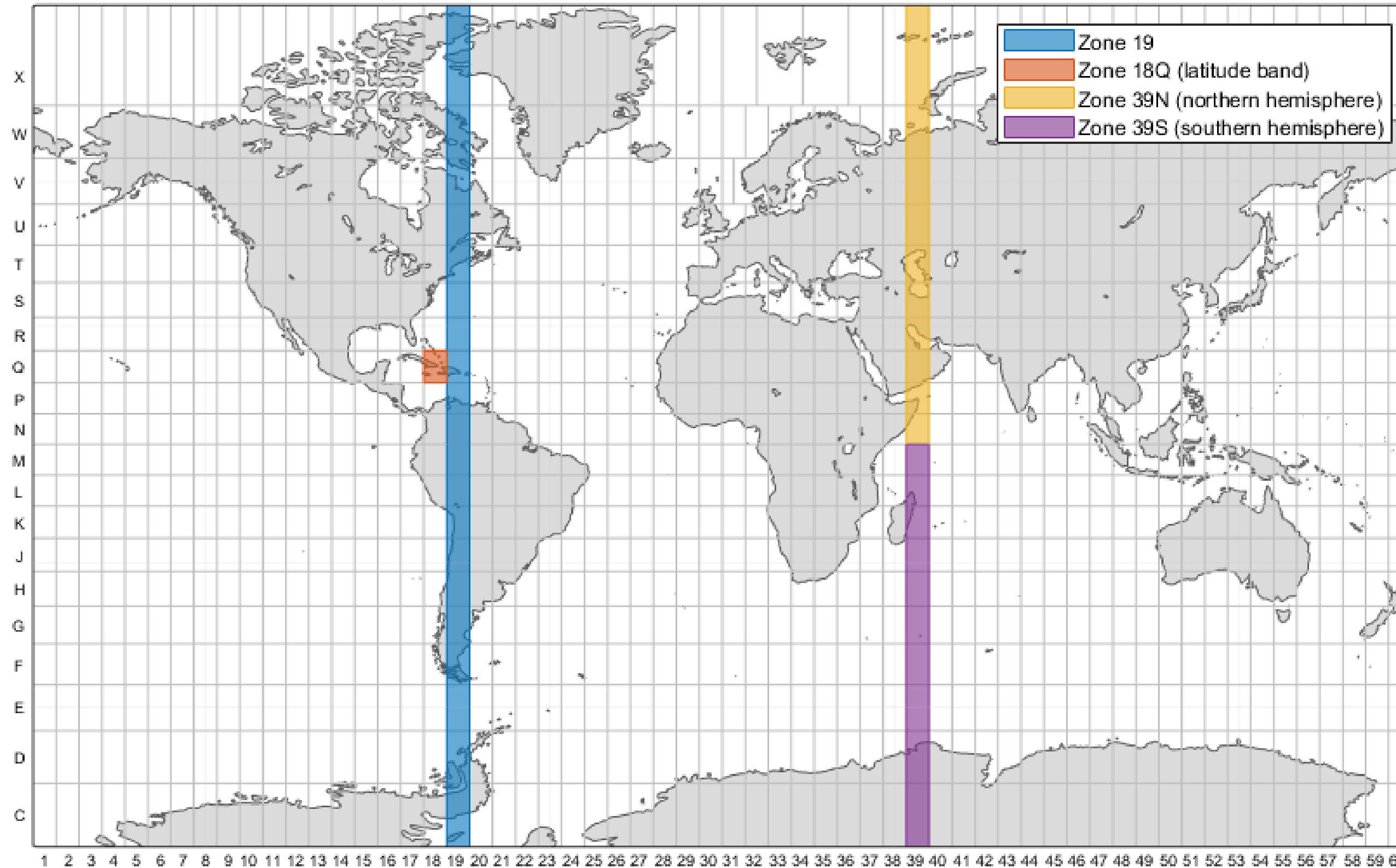
The core of UTM is the **transverse Mercator projection**, a modified version of the original Mercator projection. It's used to project a cylindrical surface onto the Earth, with the cylinder touching a meridian instead of the equator. This helps to minimize distortions in areas away from the equator.

Zones: Each zone has a unique central meridian and a specific scale factor to ensure accuracy. This helps to manage the distortion that occurs when projecting a spherical surface onto a flat map.



<https://gisgeography.com/utm-universal-transverse-mercator-projection/>

Universal Transverse Mercator - UTM



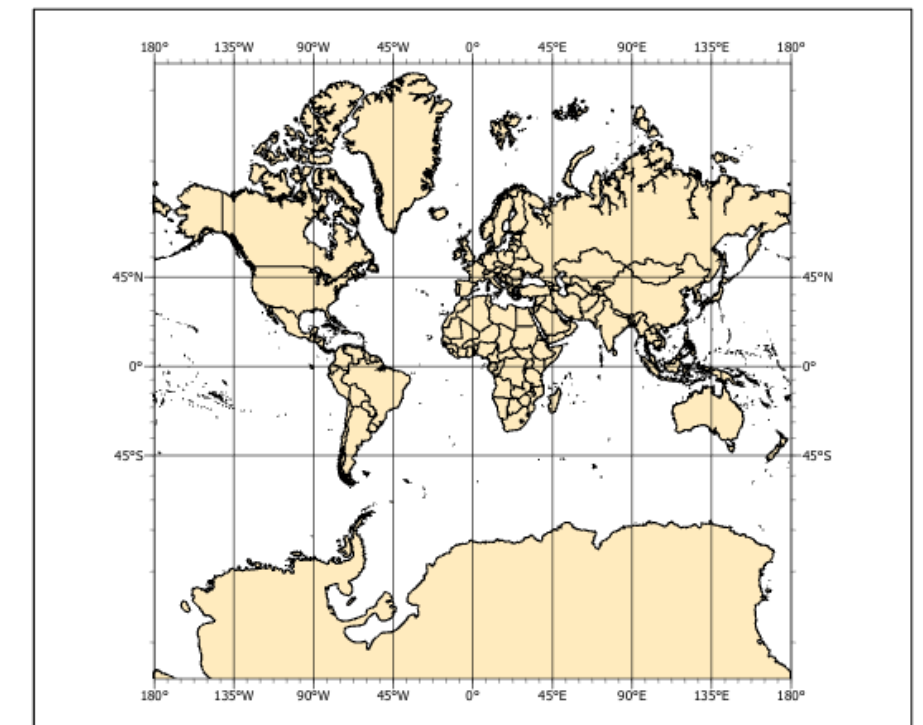
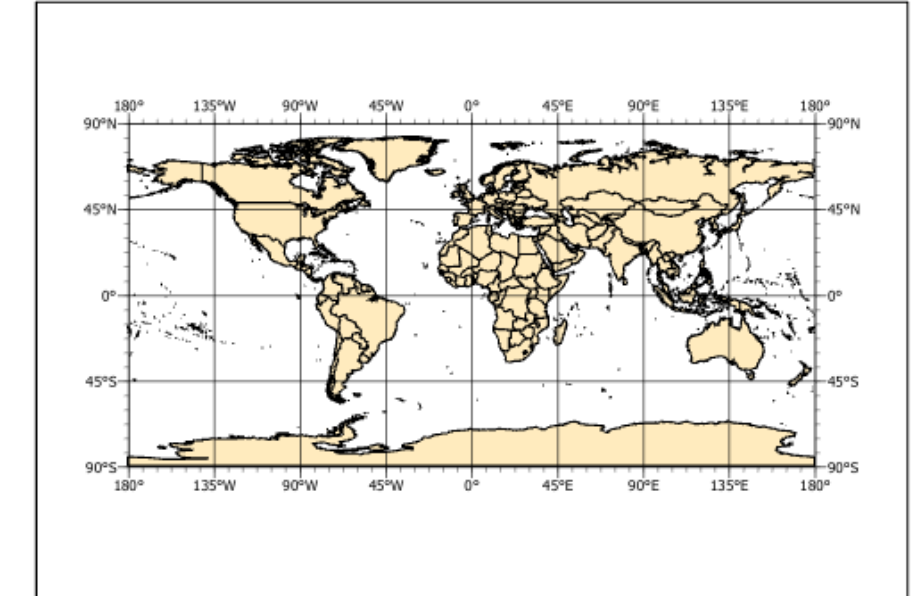
<https://de.mathworks.com/help/map/create-utm-maps.html>

EPSG Codes

EPSG provides a universal coding system for identifying coordinate reference systems and transformations.

Each **EPSG code** uniquely identifies a **CRS** or a **coordinate transformation**. When users enter an EPSG code into a GIS platform, the system uses the parameters associated with that code (ellipsoid, datum, projection, etc.) to correctly interpret or transform the geospatial data.

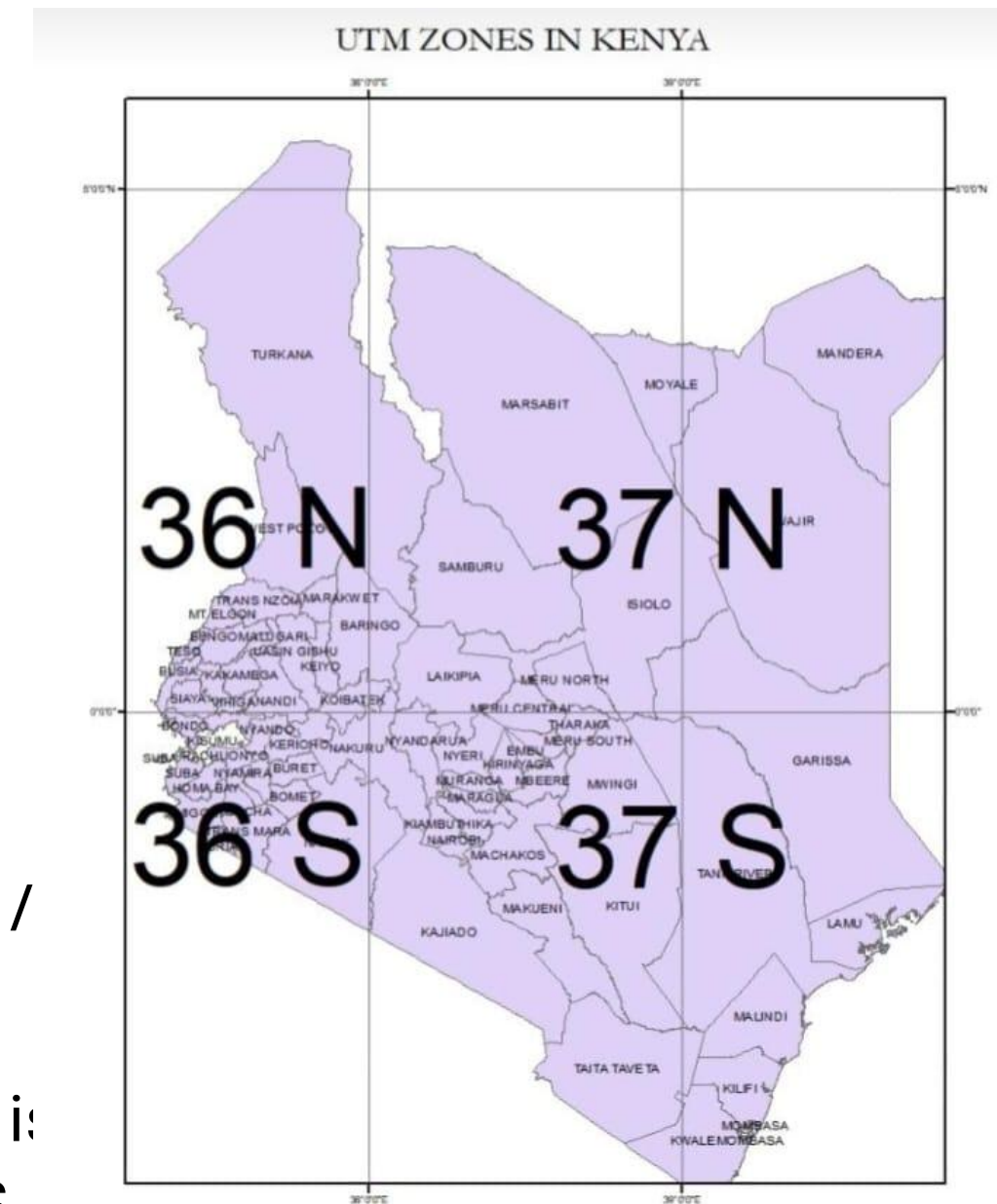
- For example:
- **EPSG:4326** (WGS 84, latitude/longitude) is commonly used for global datasets, such as satellite imagery or GPS coordinates.
- **EPSG:3857** (Web Mercator projection) is used in web mapping platforms like Google Maps, Bing Maps, and OpenStreetMap.



Map projections for Kenya

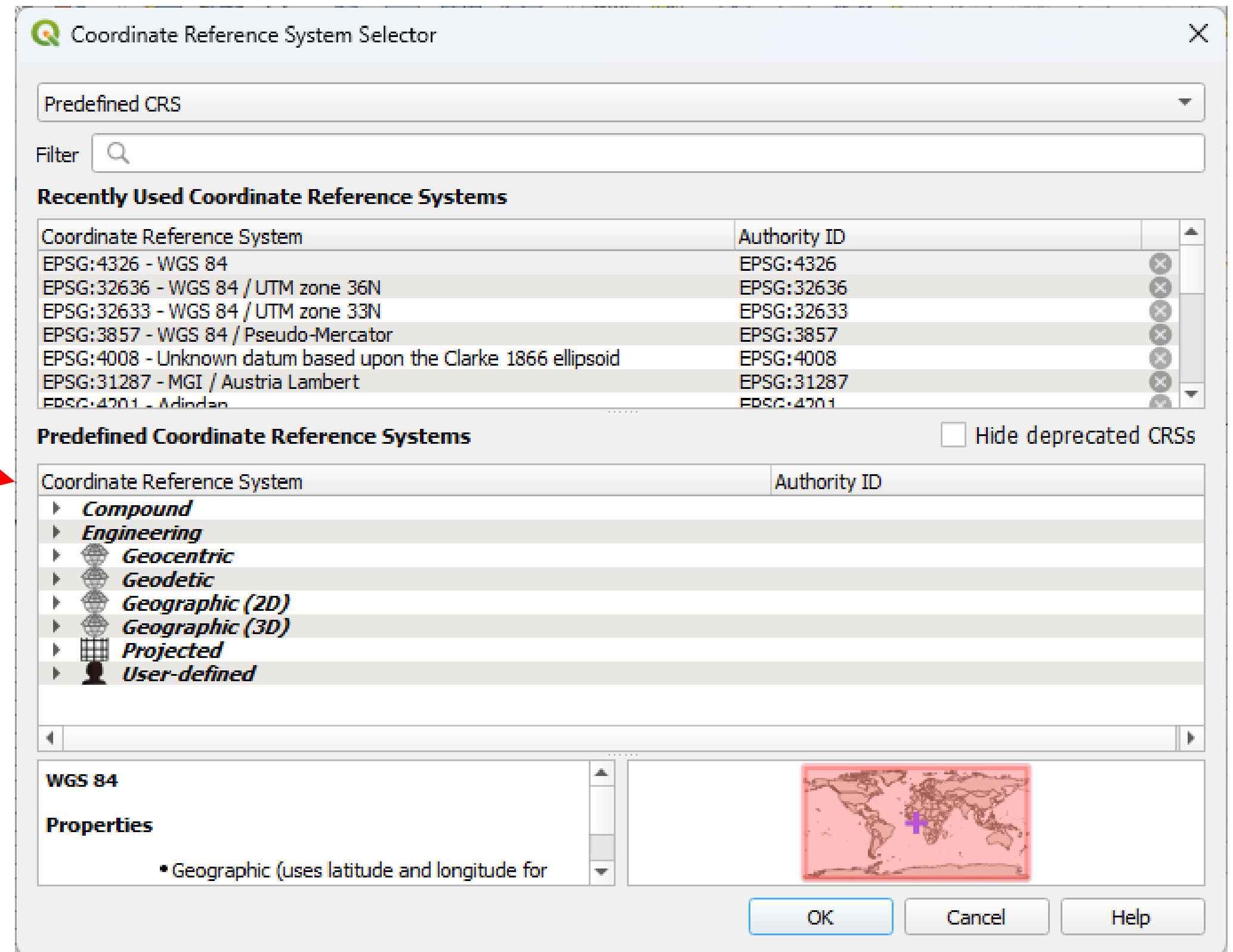
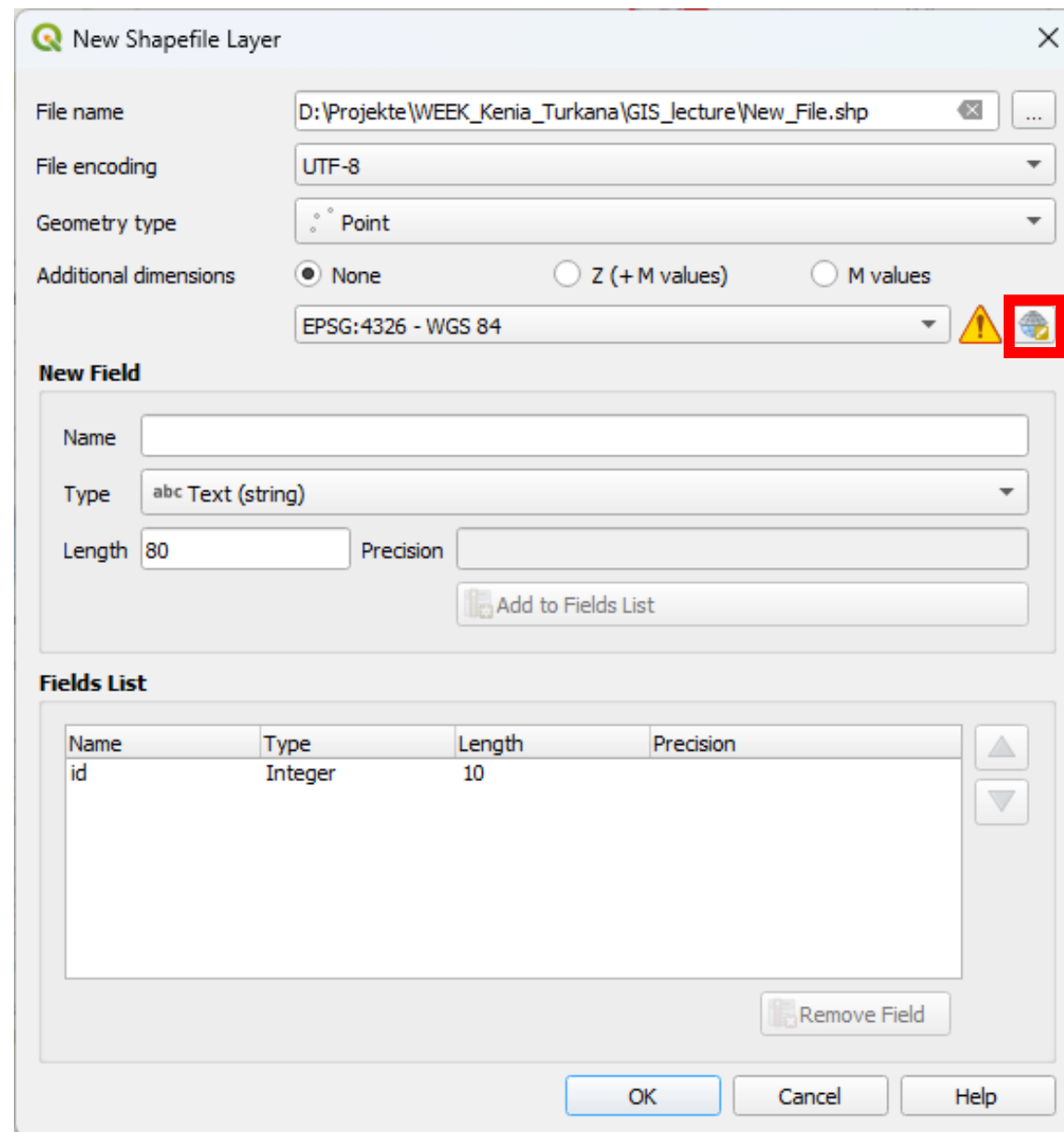
The most common and official projection is a version of the **Universal Transverse Mercator (UTM) projection**.
UTM Zones: Kenya spans two main UTM zones in both the northern and southern hemispheres:

- Zone 36N (for the northern part of the country): **EPSG: 32636**
- Zone 37N (for the northern part of the country, east of 36°E): **EPSG: 32637**
- Zone 36S (for the southern part of the country): **EPSG: 32736**
- Zone 37S (for the southern part of the country, east of 36°E): **EPSG: 32737**
- **Datums:**
 - **Arc 1960:** This is the older, traditional datum used for official government mapping by the Survey of Kenya. It is based on the Clarke 1880 (modified) ellipsoid. You will often see coordinate reference systems (CRS) like Arc 1960 / UTM zone 37N (EPSG: 21097) or Arc 1960 / UTM zone 37S (EPSG: 21037).
 - **WGS 84:** This is the global standard for modern mapping and GPS systems. It is the most common datum for data exchange and is widely used in modern GIS applications.



Map projections in QGIS

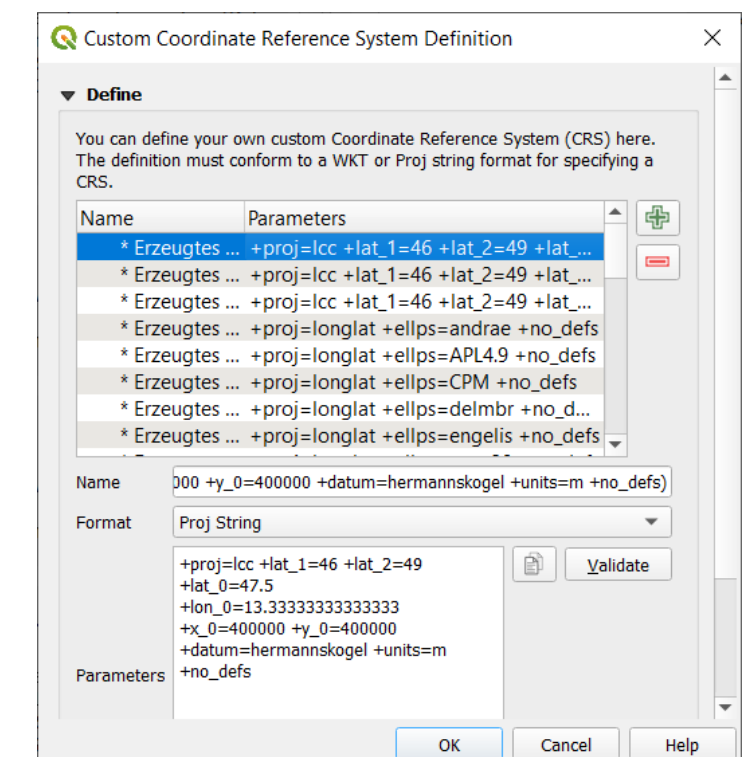
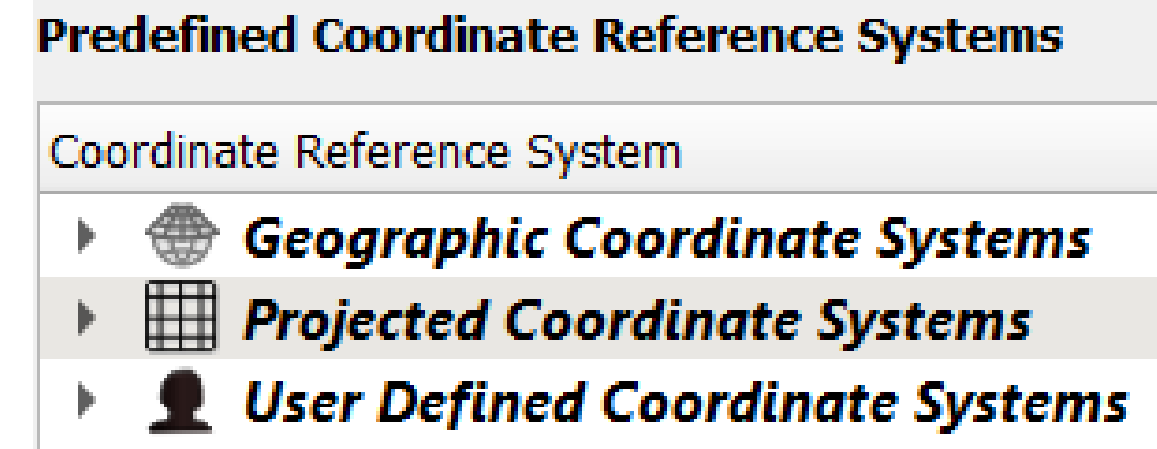
- **Definition of new layer**



QGIS: Coordinate Reference System (CRS)

The coordinate reference systems in QGIS are **based on EPSG codes** from the European Petroleum Survey Group and the Institut Geographic National de France (IGNF).

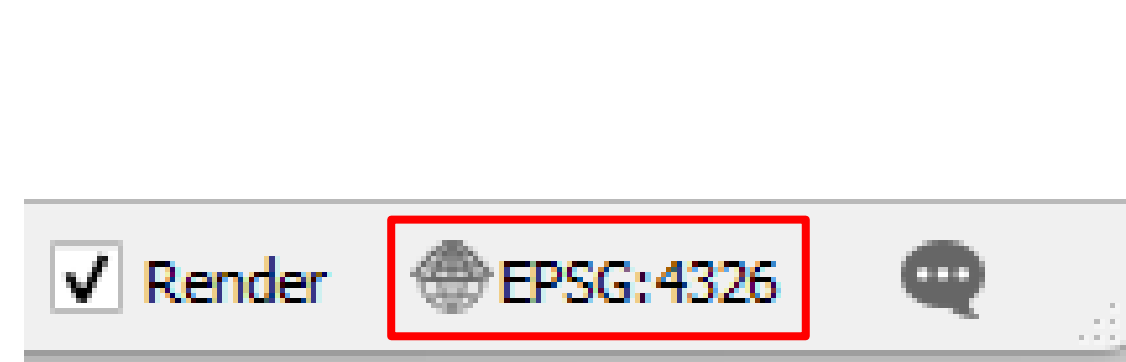
- **Geographic Coordinate Systems**
 - Ellipsoids: Arc 1960, WGS84, ETRS89 → geodetic datum
- **Projected Coordinate Systems**
 - UTM, ...
- **User Defined Coordinate System**
 - See „Settings – Custom projections...“
 - QGIS user handbook
 - saved in a user-database



Map projections in QGIS

- **Opening a new project**

Default CRS: EPSG:4326 (WGS84)



- **Load the first layer:**

e.g.: Points_Turkana (Shape-file)



-

New CRS: EPSG: 20137 Loading additional layers with a different CRS:

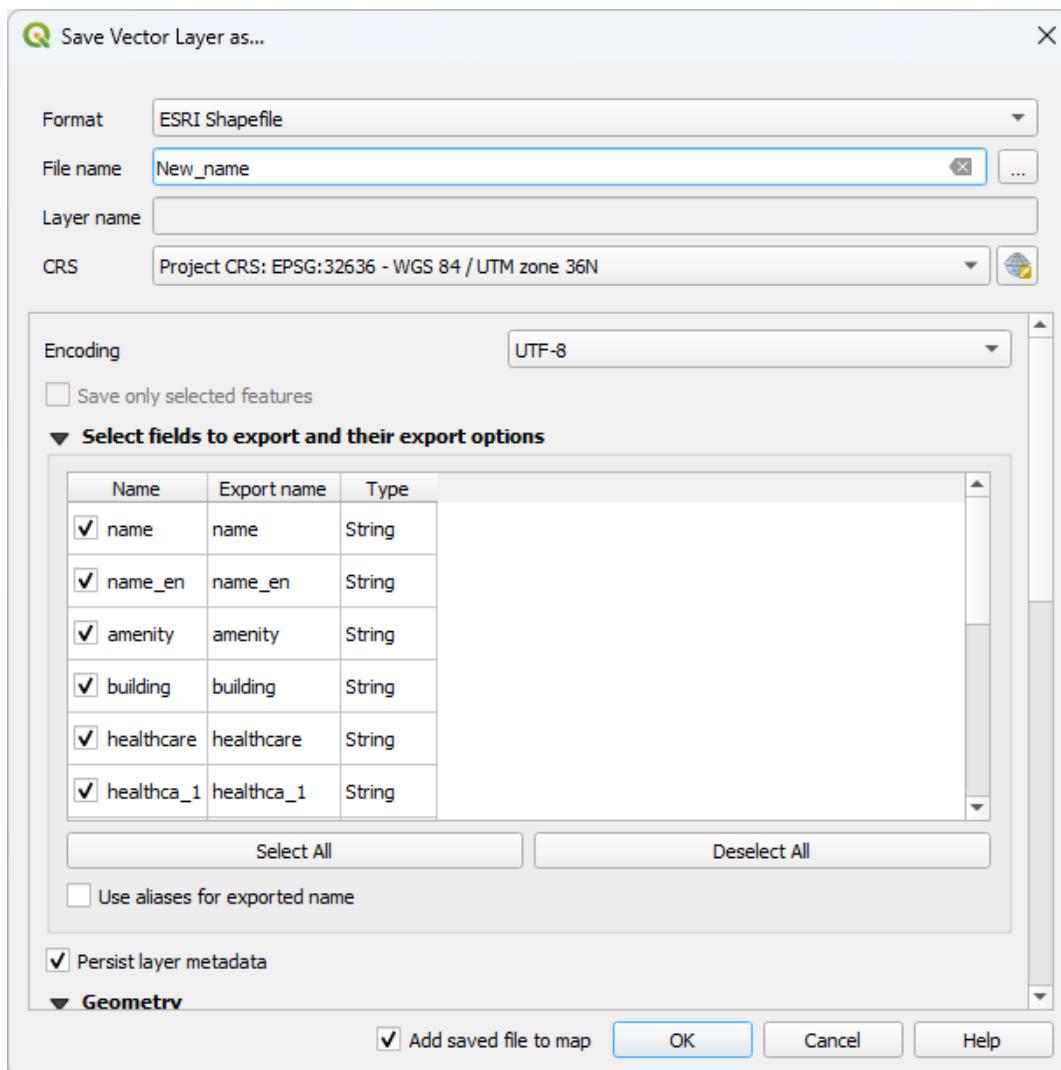
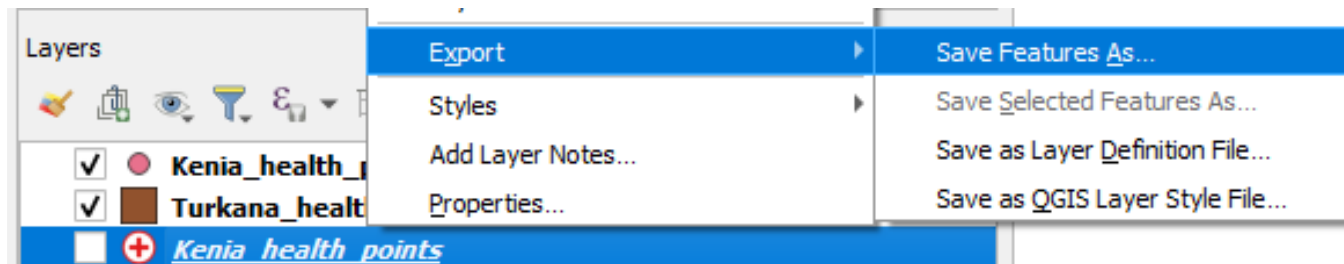
→ CRS of additional layers must be defined correctly

→ Automatic transformation (**„projection-on-the-fly“**)

- Same geodetic datum: automatic transformation
- Different geodetic datum: Query for transformation (right mouse button – properties)

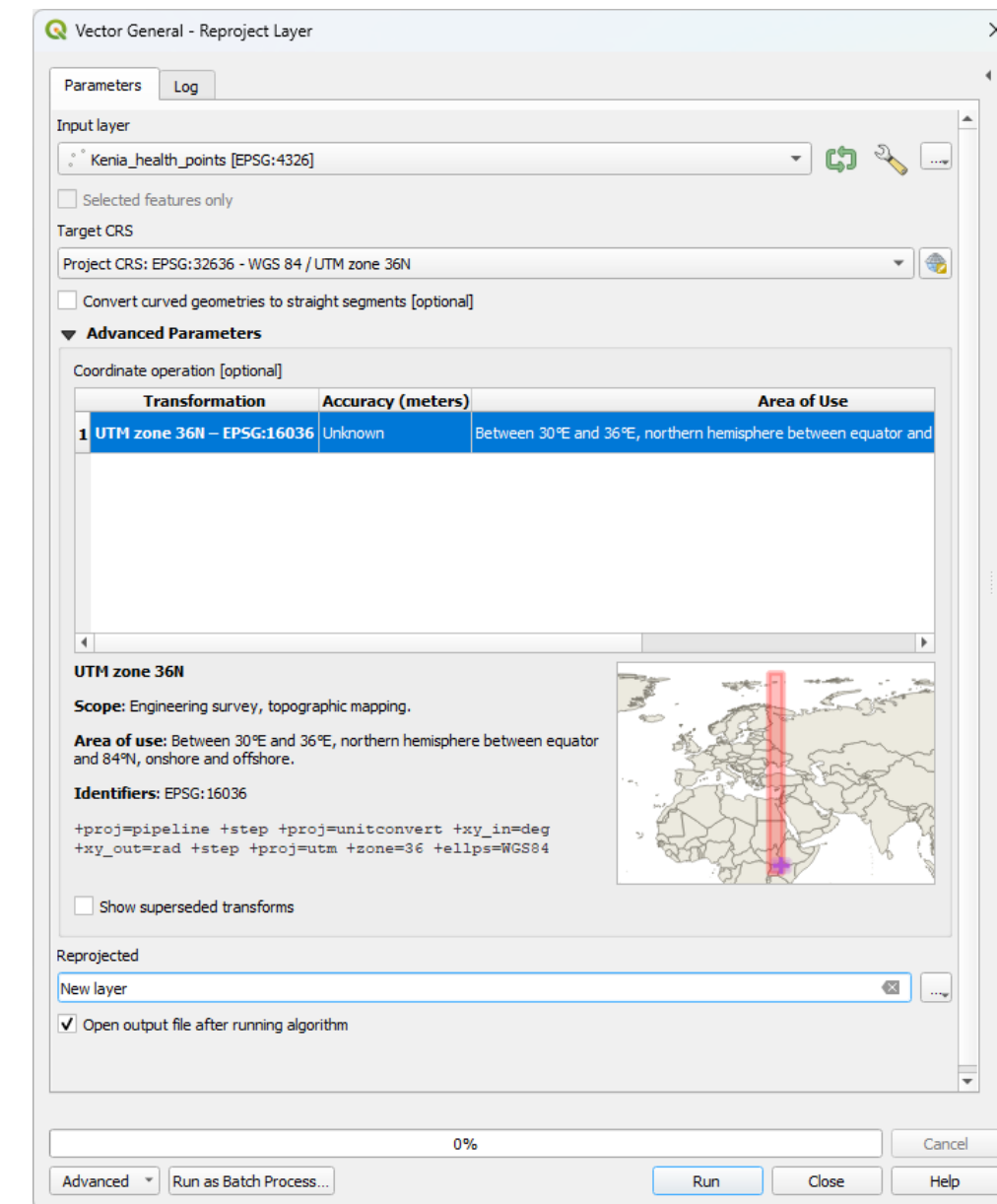
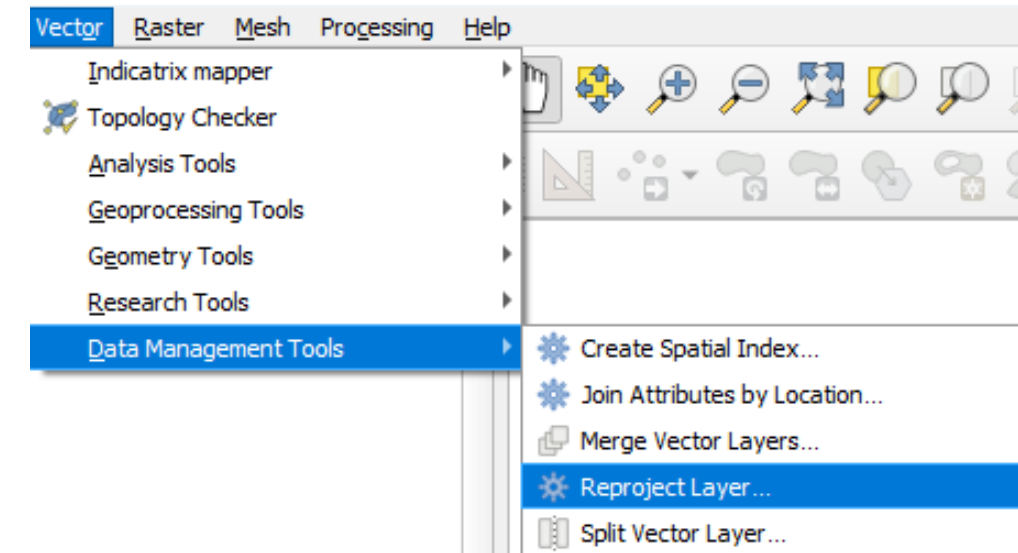
Map projections in QGIS

- **Change CRS of a layer: reproject**



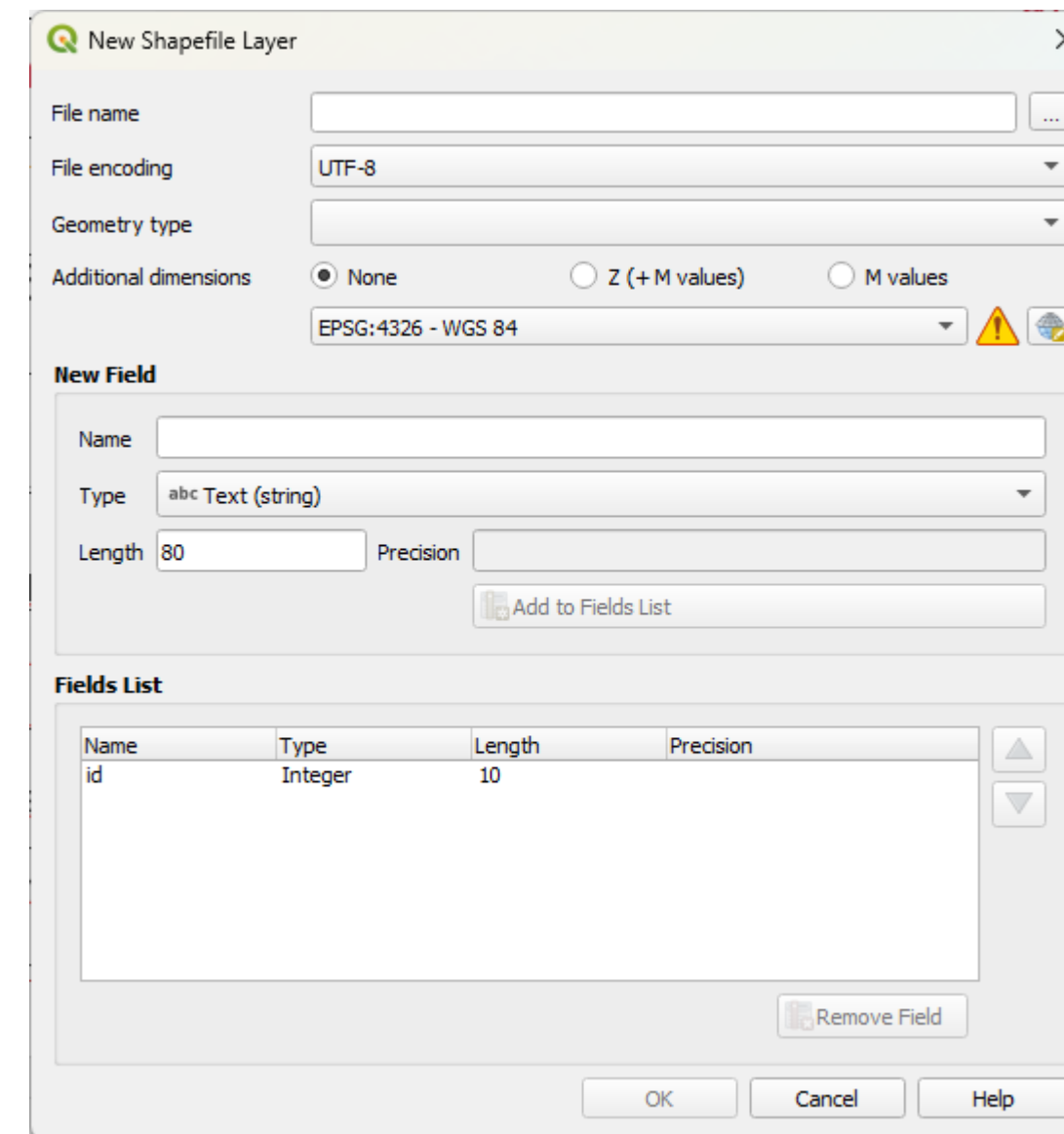
→ Export: Save feature as

→ Select new projection for the layer



EXERCISE

- **Create three Shape-Files: Point, Line, Polygon within Turkana region:**
 - CRS: UTM, Zone 36N (EPGS: 32636)
 - Attributes (Fields):
 - Attribut 1: Text (string)
 - Attribut 2: Integer (32 bit)
 - Attribut 3: Decimal (Double)



Day 1: Data acquisition

Create new data: point, line, polygon

Science for [life]

Basemaps

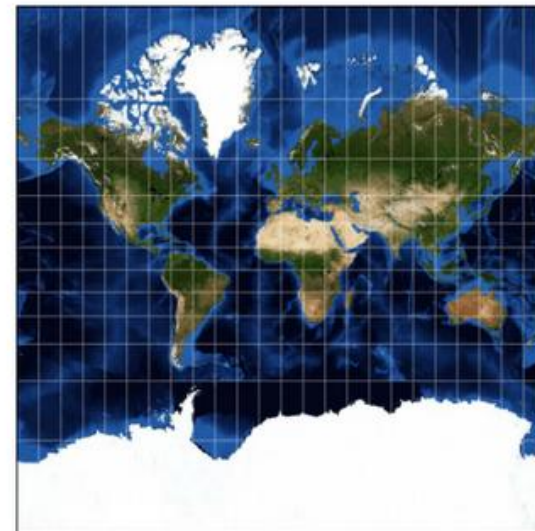
- XYZ-Tiles



Degrees
Geodetic coordinates
WGS84 (EPSG:4326)

Longitude and latitude
coordinates used by GPS devices for defining position on Earth using World Geodetic System defined in 1984 (WGS84).

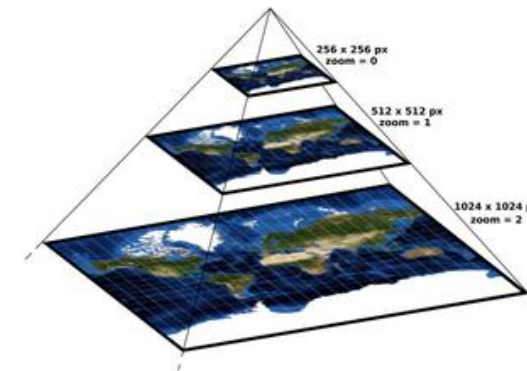
HINT: WGS84 geodetic datum specify lon/lat (lambda/phi) coordinates on defined ellipsoid shape with defined origin ([0,0] on a prime meridian).



Meters
Projected coordinates
Spherical Mercator
(EPSG:3857)

Global projected coordinates in meters for entire planet. Used for raster tile generation in GIS and WM(T)S services.

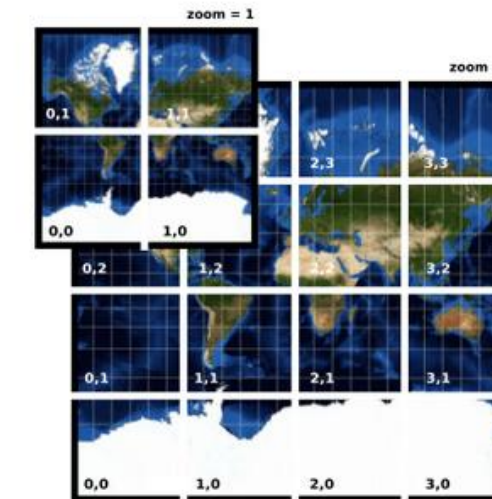
HINT: Simpler spherical calculation are used instead of ellipsoidal. Mercator map projection deforms size (Greenland vs Africa) and never shows poles.



Pixels
Screen coordinates
XY pixels at zoom

Zoom-specific **pixel coordinates** for each level of the pyramid. Top level (zoom=0) has usually 256x256 pixels, next level 512x512, etc.

Devices calculate pixel coordinates at defined zoom level and determine visible viewport for area which should be loaded from servers.



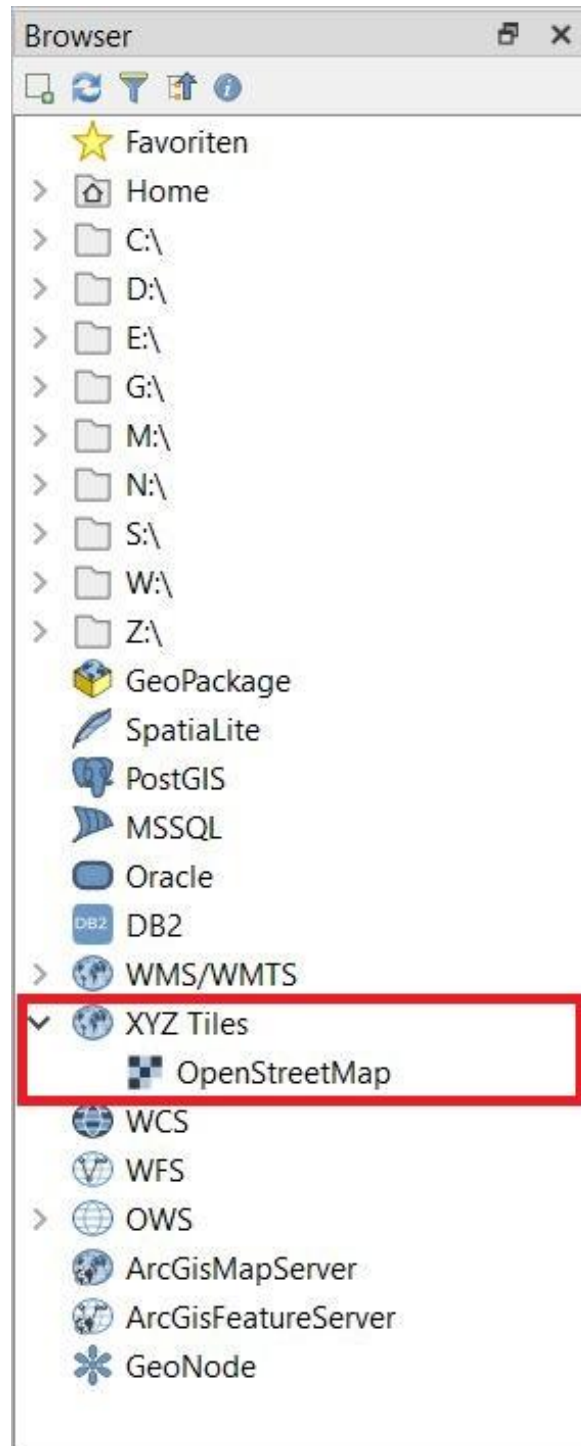
Tiles
Tile coordinates
Tile Map Service (ZXY)

Coordinates of a **tile in the pyramid**. There is one tile on the top of the pyramid, than 4 tiles, 16 tiles, etc. All tiles have the same size, usually 256x256 pixels.

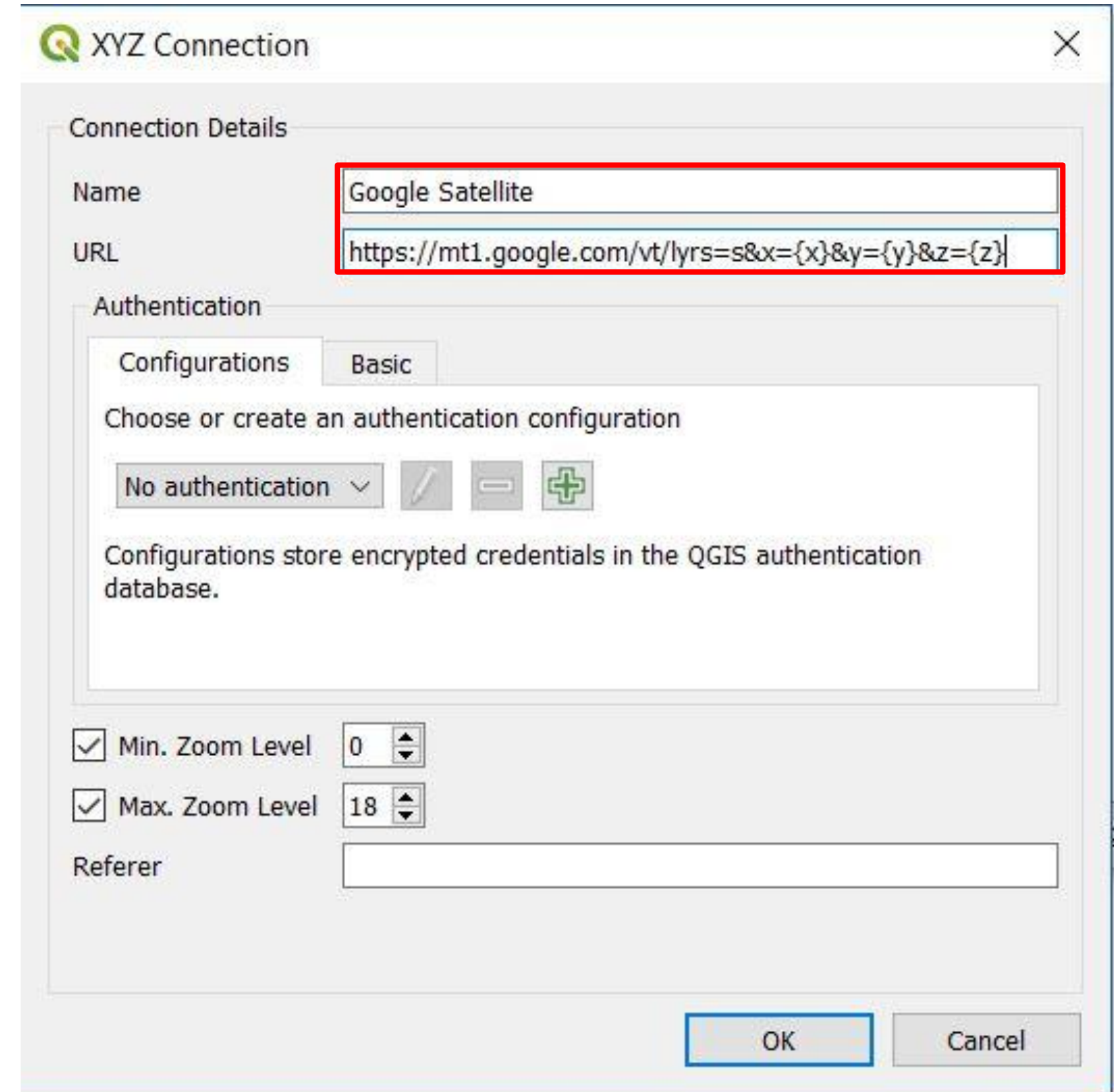
Only the relevant tiles loaded and displayed for the area of interest / viewport.

Add XYZ-Tiles

- **Browser Panel**



OpenStreetMap: pre-installed
 Adding new XYZ Tiles
 → Right-click on XYZ Tiles



Add XYZ-Tiles

- Integration of various (globally available) base maps via XYZ tiles:

- **OpenStreetMap:** https://wiki.openstreetmap.org/wiki/Tile_servers

<http://tile.openstreetmap.org/{z}/{x}/{y}.png>

- **Google Hybrid**

<https://mt1.google.com/vt/lyrs=y&x={x}&y={y}&z={z}>

- **Google Satellite**

<https://mt1.google.com/vt/lyrs=s&x={x}&y={y}&z={z}>

- **Google Road**

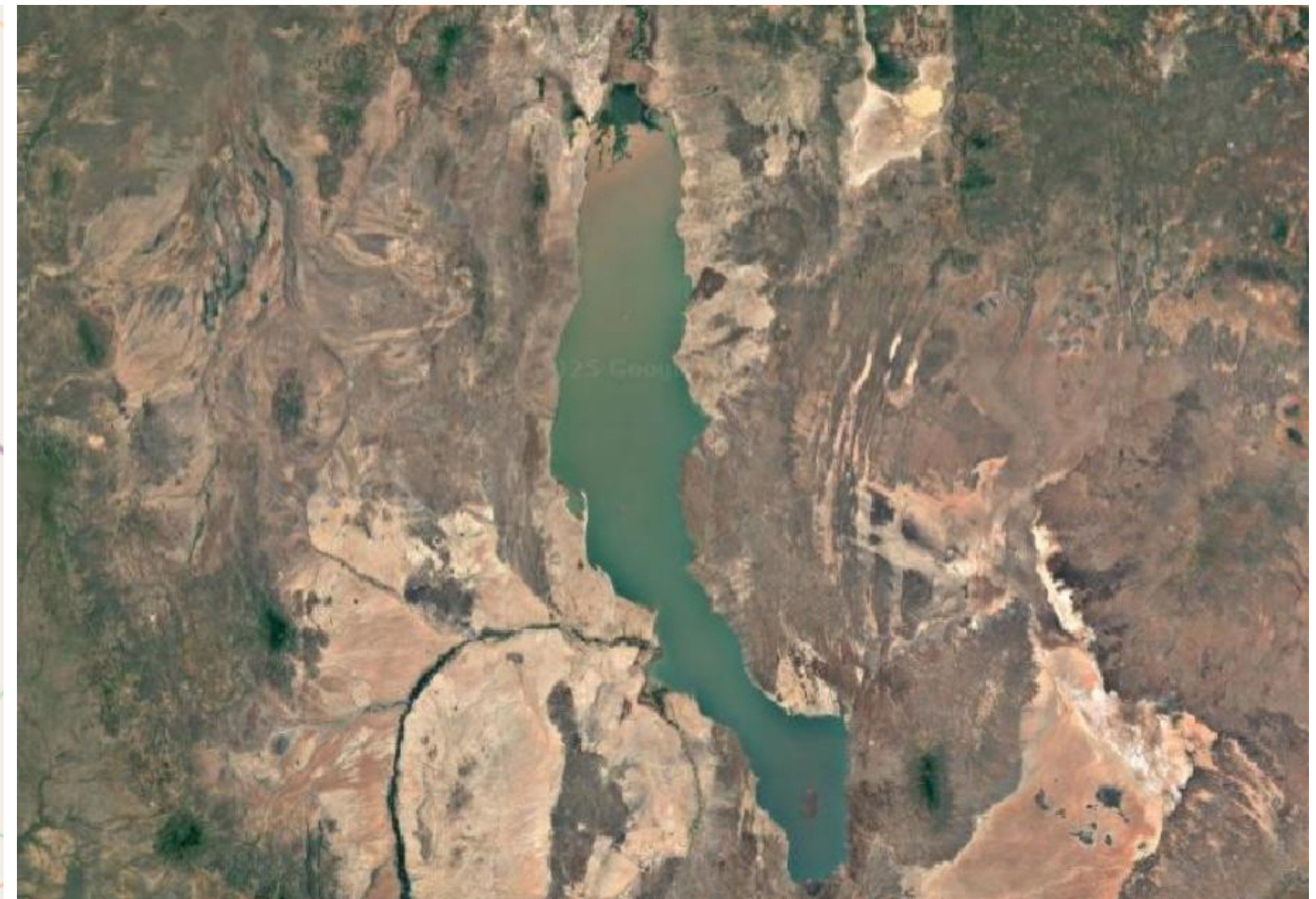
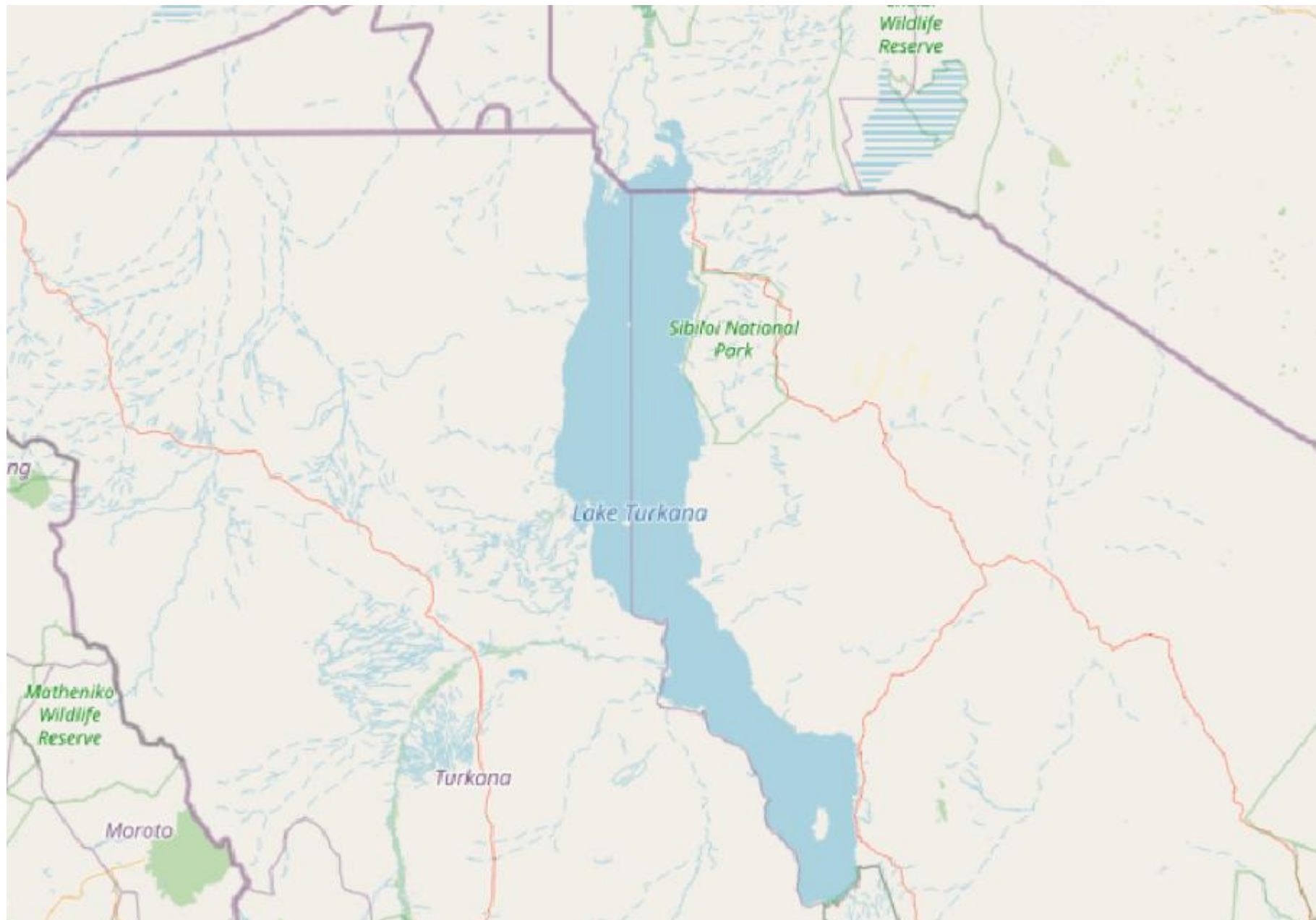
<https://mt1.google.com/vt/lyrs=m&x={x}&y={y}&z={z}>

- **Bing Aerial**

<http://ecn.t3.tiles.virtualearth.net/tiles/a{q}.jpeg?g=1>

Add XYZ-Tiles

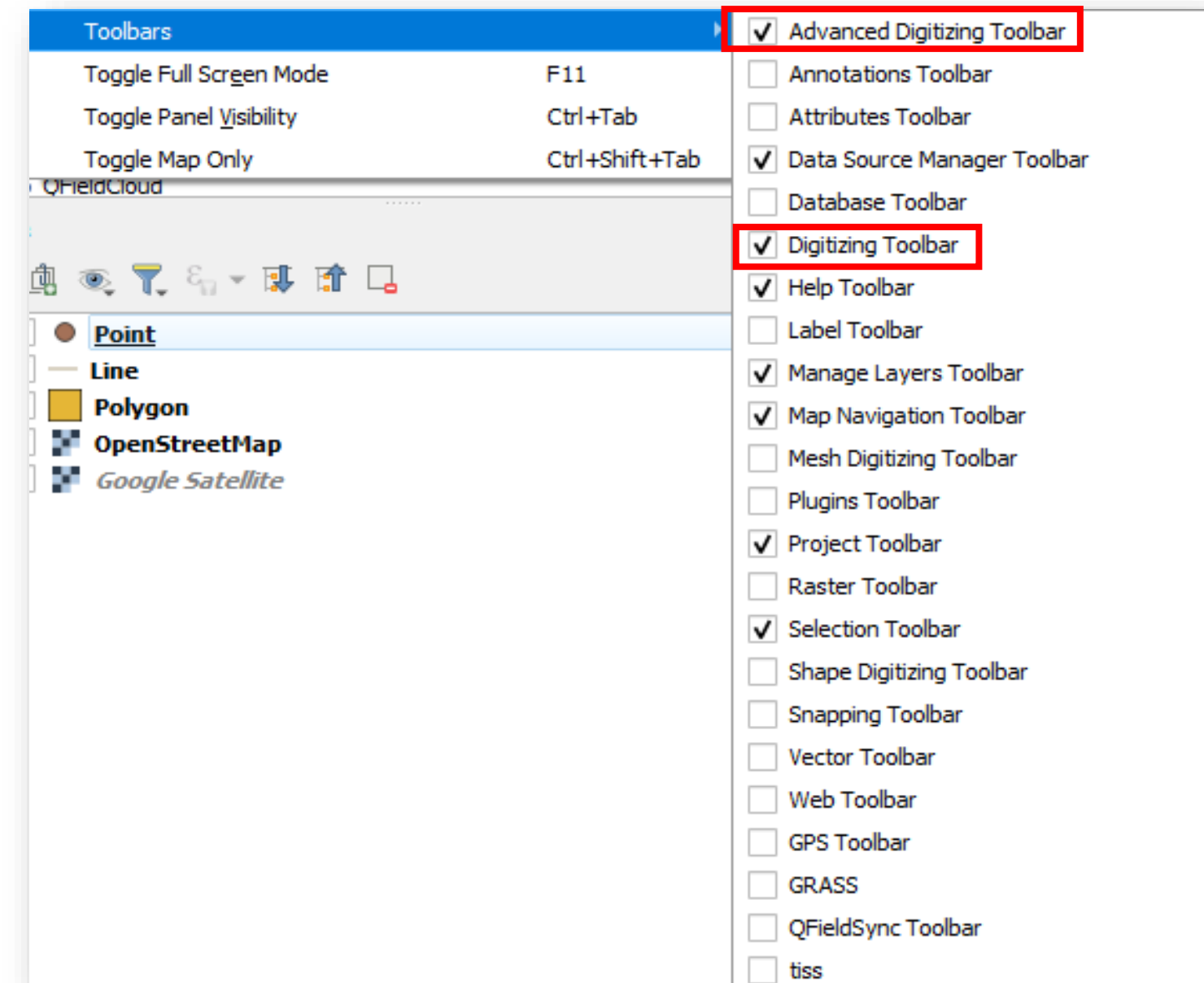
- **Example: OpenStreetMap and Google Satellite:**
 - CRS: WGS 84/Pseudo Mercator (EPSG: 3857) → Web Mercator Auxiliary Sphere



Loading data and toolbars

- Load data to edit (point, line, polygon layers)
- Load background maps (Google, OpenStreetMap)
- Load toolbars for editing data: Digitizing Toolbar, Advanced digitizing Toolbar

View - Toolbars



Editing data

- **Tools**



- **Recent changes:** this pull-down menu can be used to save changes, discard objects, etc.
- **Toggle editing status:** Turn editing mode on and off.
- **Save layer changes:** when objects are drawn, they are first stored in the cache and **only when they are saved, the changes are saved to the hard disk in the Shape file or GeoPackage-layer.**
- **Digitize with segment, digitize with curves, ...**
- **Add Object:** this allows you to draw new objects by setting vertices (see below). The button looks different for points or polygons.
- **A newly drawn object is terminated by clicking the right mouse button**

Editing data

- **Tools**



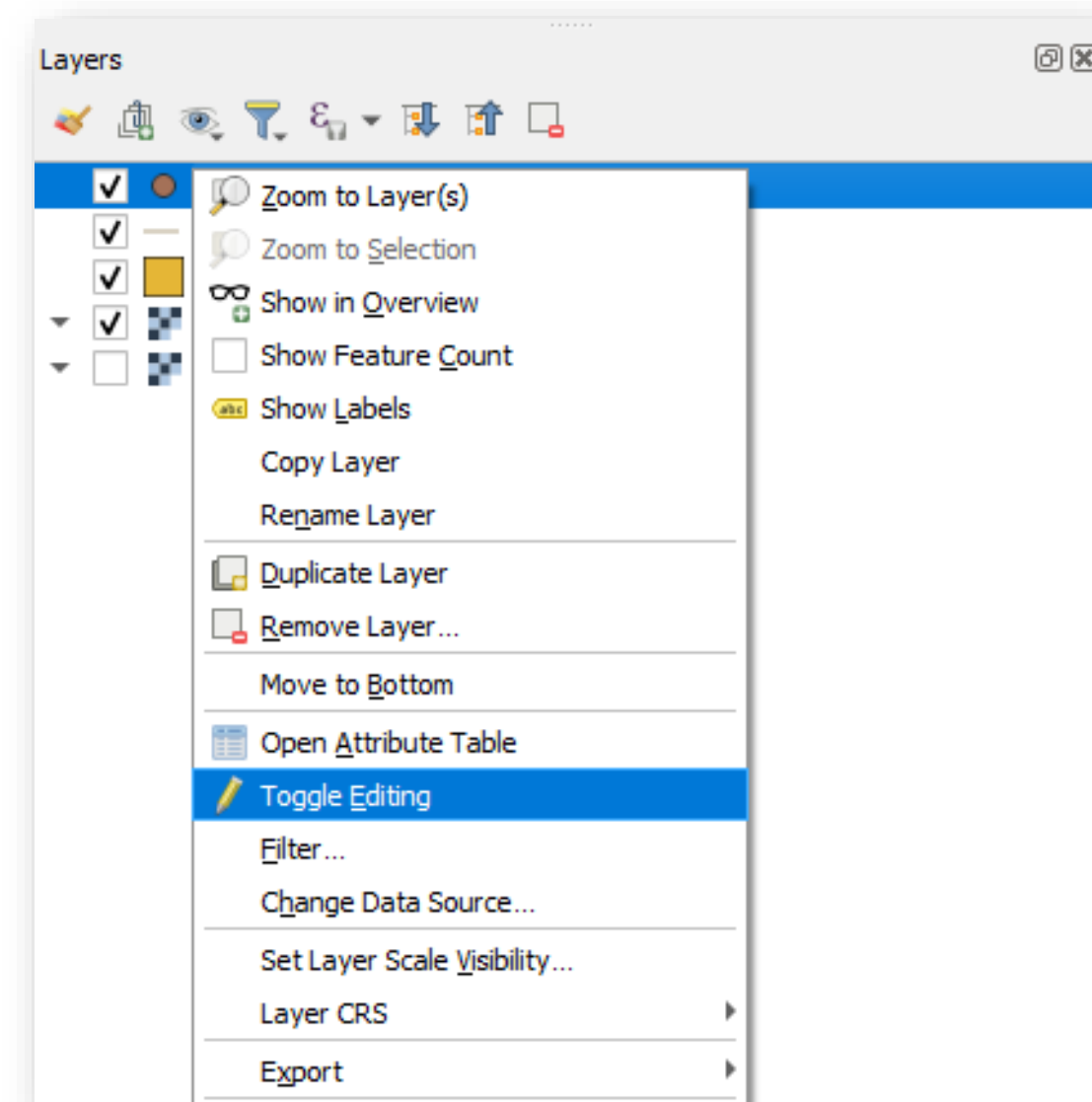
- **Vertex tool:** Lines are made up of nodes (vertices) and edges. The nodes can be edited with this tool. If you click on the line, the nodes become visible. Right-clicking on an edge inserts a new node, which can then be moved. In addition to moving selected nodes (blue), they can also be deleted with the Delete key. The selection is made by clicking on the node or by selecting a node via the Vertex Editing window.



- Change attributes, delete, cut, copy
- **Undo, Redo**

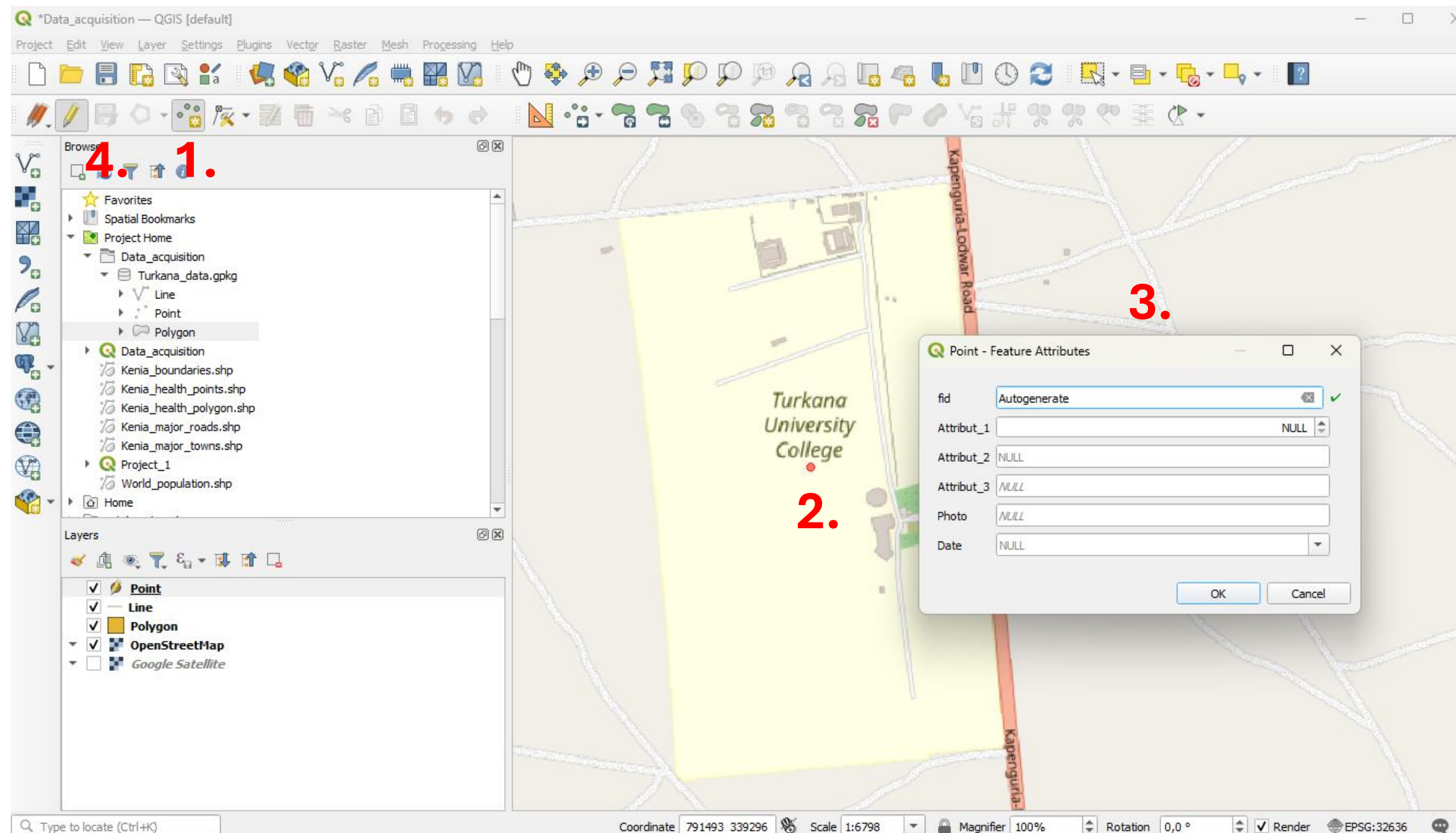
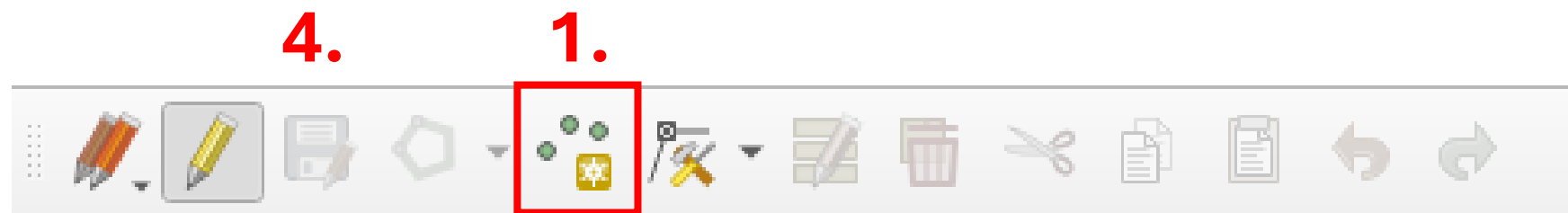
Start editing

- 1. Select the layer you want to edit:** click on the layer name with the left mouse button in the layer window. For example: point
- 2. Start editing mode:** Activate the pen in the Digitizing toolbar. Or right-click on the name in the Layer panel and select “**Toggle Editing**”. After that, the other tools are (partially) activated.



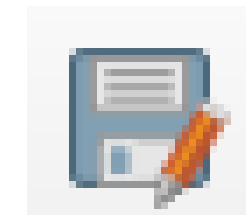
Editing point, line or polygons

- Point



1. Select „Add Point Feature“
2. Click on a point in the map
3. Fill out the Feature Attributes and confirm with OK

4. Save edits!



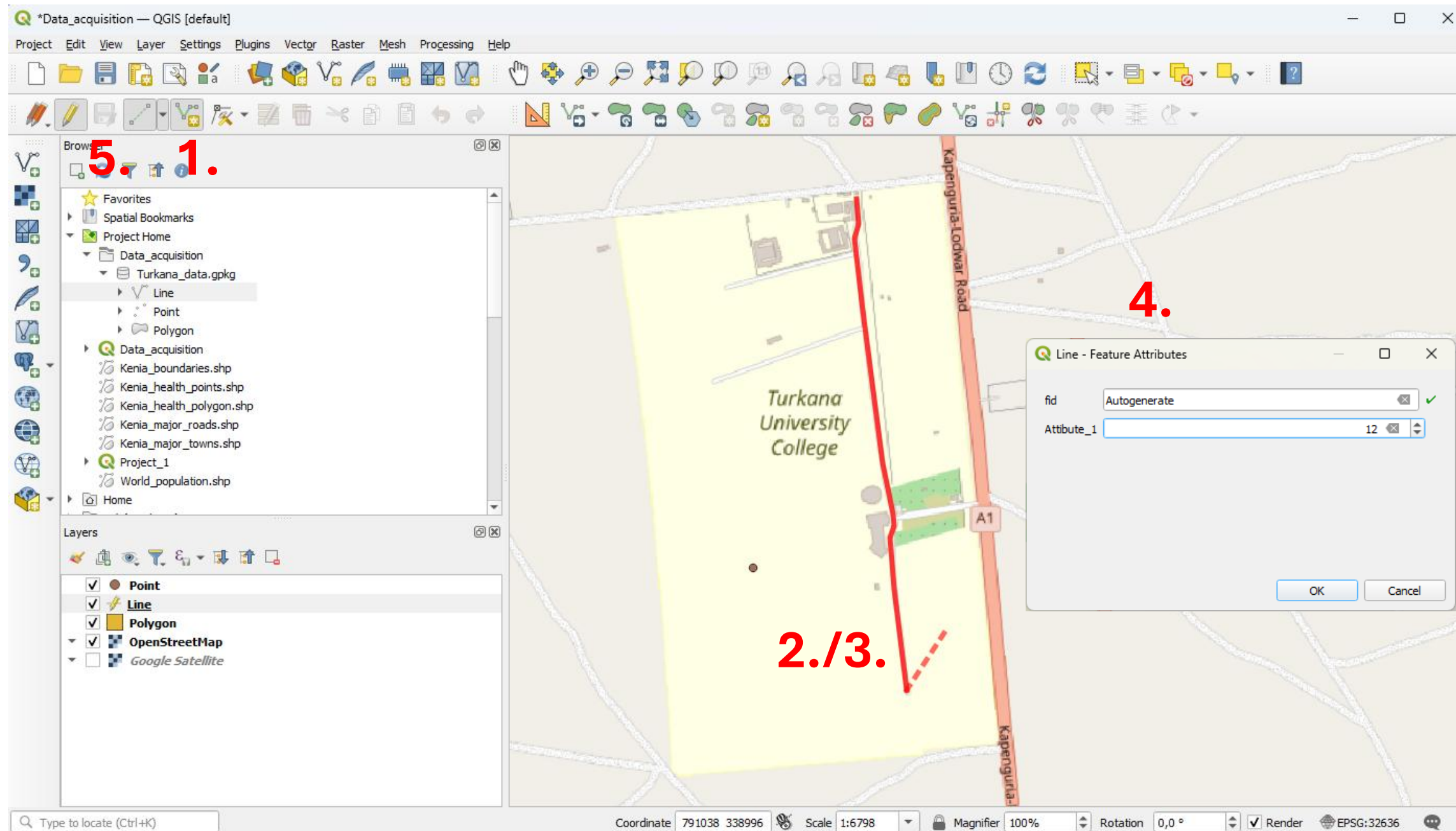
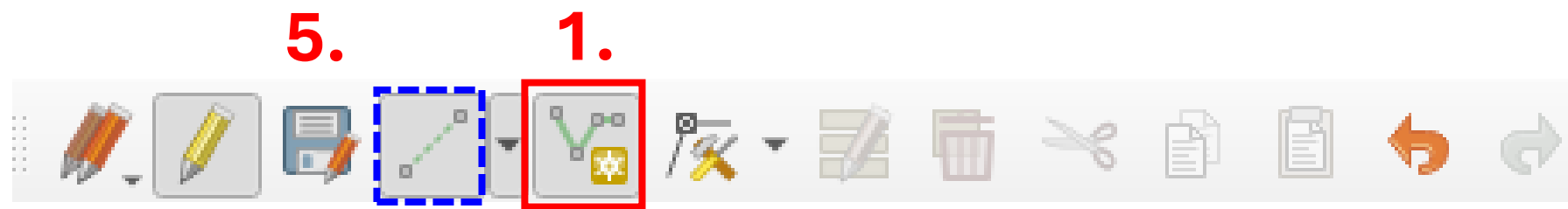
Only when features are saved, the changes are saved to the hard disk in the Shape file or GeoPackage-layer!

5. At the end: stop editing

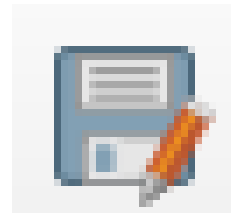


Editing point, line or polygons

- **Line**



1. Select „Add Line Feature“
2. Set vertices with left mouse button
3. Finish feature (line) with right mouse button
4. Fill out the Feature Attributes and confirm with OK
5. Save edits!



Only when features are saved, the changes are saved to the hard disk in the Shape file or GeoPackage-layer!

6. At the end: stop editing



Editing point, line or polygons

- Polygon

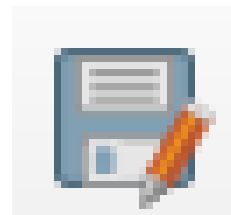
5. 1.

5. 1.

4.

2./3.

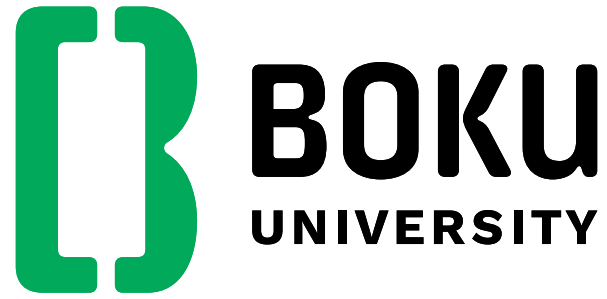
1. Select „Add Polygon Feature“
2. Set vertices with left mouse button
3. Finish feature (polygon) with right mouse button
4. Fill out the Feature Attributes and confirm with OK
5. Save edits!



Only when features are saved, the changes are saved to the hard disk in the Shape file or GeoPackage-layer!

6. At the end: stop editing





Thank you!

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