An Introduction to Geographic Information System

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1 MODULE 1: Overview of the basic concept of Geographic Information System.

1.1 Objectives:

This module enables the students to:

1. Possess knowledge of the basic GIS concepts;
2. Gain knowledge about GIS data models and structures and;
3. Understand the Coordinate reference systems (CRS).

1.2 Outcomes:

After reading this module, students should be able to:

1. Define what is GIS;
2. Differentiate vector from raster;
3. Familiarized with the common Coordinate Reference Systems (CRS)

1.3 Definition of Terms

1.4 Basic GIS Concept

This module aims to provide a discussion about basic Geographic Information System (GIS). The discussions about GIS in this module are not comprehensive and are intended for beginner students. Further readings and resources are provided at the end of this module for students who wish to learn more about the science and art of GIS.

Through the years, the improvement and development of computers has revolutionized map making. This revolution helped cartographers to shift from tedious hand-drawn maps to digital maps. GIS allows anyone to visualize spatial data in space and in an interactive manner.

Geography is a core and essential element at the heart of GIS. By definition, it means the study of locational and spatial variation in both physical and human phenomena on earth(Balasubramanian 2014). In other words, one cannot fully grasp or implement GIS without considering the principles and concepts of geography.

> ℹ Important Reminder:
>
> In the context of GIS, geography refers to the spatial relationships and characteristics of features on the Earth's surface.

By utilizing GIS, it is possible to incorporate a geographical aspect to any data by linking it to specific locations. This is accomplished through techniques such as Geo-tagging and Geo-referencing. Data or information that is tied to a specific location is referred to as ***geospatial***.

1.4.1 What is Geographic Information System (GIS)

GIS is a computer-based system that is designed to capture, manipulate, analyze, manage, retrieve, and display all types of geographically reference data.

> ! Keep in Mind:
>
> `The keywords are: Computer-based, System, and geographically-referenced.`

The primary function of GIS is not just to create maps but also to display data in a spatially explicit manner. This enables users to identify emerging patterns and gain a better understanding of phenomena.

1.4.2 Comparison between GIS and Mapping

GIS is often associated with maps, but it is important to understand that it encompasses much more than just mapping. While maps are a way to display data in a spatially explicit manner, GIS is a broader concept that includes many different applications. In fact, GIS is an umbrella term that refers to a variety of tools and techniques used to analyze, manage, and visualize geospatial data.

Keep in mind:

GIS is not equivalent to ***"Mapping"***
GIS is " ***Mapping plus more***"

1.4.3 GIS as a System

GIS may appear as a single entity, but it is actually a system consisting of a collection of components working together to perform a particular function. As a system, GIS comprises various elements connected and integrated in a cohesive manner. Like any other system, GIS is composed of numerous components, including but not restricted to:

Table 1: Common Components of a GIS

• Computer	• Hardware
• Software	• Procedures and methods
• Data	• People

Important Note:

GIS as a system is a complex network of organized and interconnected elements which includes the following: a.) Physical (hardware, people, print maps) b.) Intangible (methods, procedures, digital data).

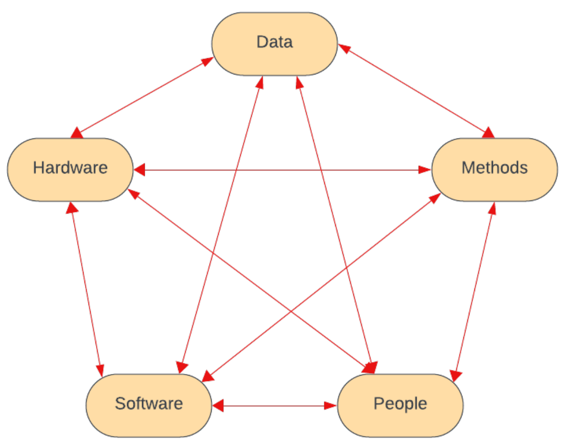


Figure 1: GIS as a System

1.4.4 The Concept of Geospatial Data

Geospatial data refers to any data that has a location component and can be displayed digitally.

> **!** Important Note:
>
> The prefix **"Geo"** suggests **"Earth"** while **"Spatial"** comes from the root word **"Space"**. The term **"Features"** is also sometimes used to refer to the vector type of GIS.

In geospatial data, anything occurring on, above, or below the Earth's surface is included. The term is often used interchangeably with spatial data or GIS data.

Table 2: Interchangeable Terms

• Spatial Data	• Geospatial Data
• Geographic Data • Vector Data	• GIS Data • Feature Data

1.4.5 GIS Data Models

There are two general types of data in GIS these are **"Vector"** and **"Raster"**.

1.4.5.1 Raster

The raster data model, along with the vector data model, is one of the earliest and most widely used data models within geographic information systems (Tomlin 1990). It is typically used to record, analyze, and visualize data with a continuous nature such as elevation, temperature, or reflected or emitted electromagnetic radiation. The term raster originated from the German word for ***screen***, implying a series of orthogonally oriented parallel lines.

1.4.5.2 Pixels and Resolution

Each tiny square of information in a digital image is called a ***Pixel***. These Pixels, or "cells," are responsible for representing features on, above, or below the earth's surface. Unlike vectors, rasters are resolution-dependent. This means that the quality of the data is influenced by the size and number of Pixels used to cover a fixed unit area.

When you zoom-in very closely on a digital image, the amount of detail you see is determined by the size of the Pixels. The resolution is dictated by the pixel size expressed in ground units, as determined by the Coordinate Reference System (CRS).

> Important Tips:
>
> "**Picture Element**" or "**Pixel**" is the smallest unit of information in a raster.

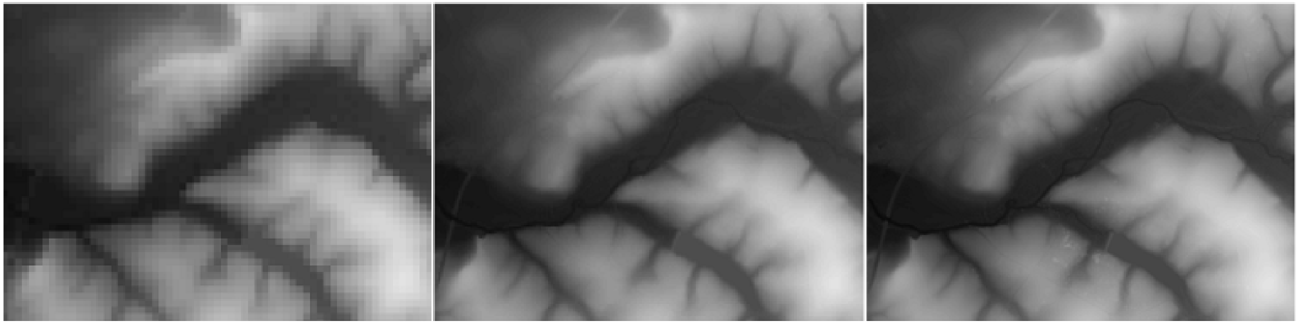


Figure 2: A Digital Elevation Model (DEM) at 30 m (left) , 10 cm (center), and 3.3 m resolution (right) Pingel (2018)

1.4.5.3 Vector

Vector data models represent spatial features using points and their associated X, Y coordinate pairs, similar to a hand-drawn map. There are three types of vector data these are Points, Lines, and Polygons.

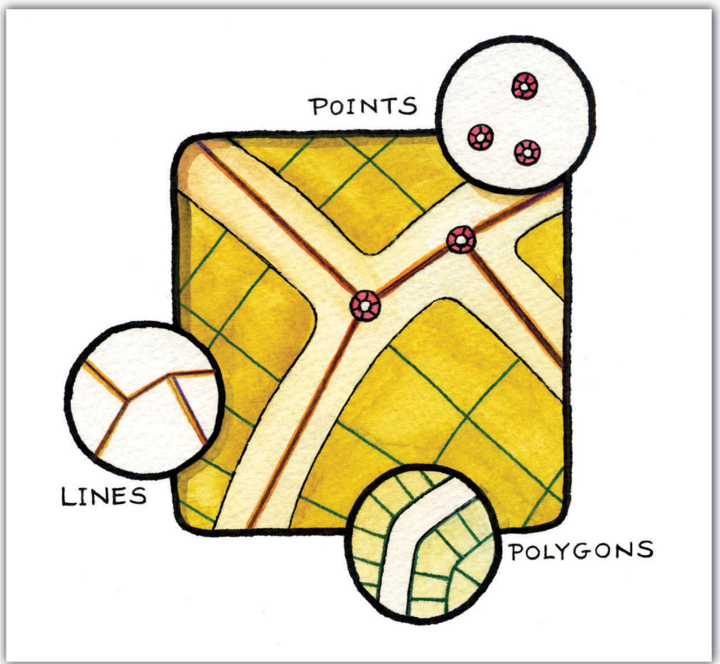


Figure 3: Points, Lines, and Polygon Sumer, Sumer, and Atasever (2015)

Points A zero-dimensional object containing a single coordinate pair. In a GIS, points have only the property of location.

Lines are one-dimensional features composed of multiple, explicitly connected points. Lines are used to represent linear features such as roads, streams, faults, boundaries, and so forth.

Polygon are two-dimensional features created by multiple lines that loop back to create a “closed” feature. In the case of polygons, the first coordinate pair (point) on the first line segment is the same as the last coordinate pair on the last line segment.

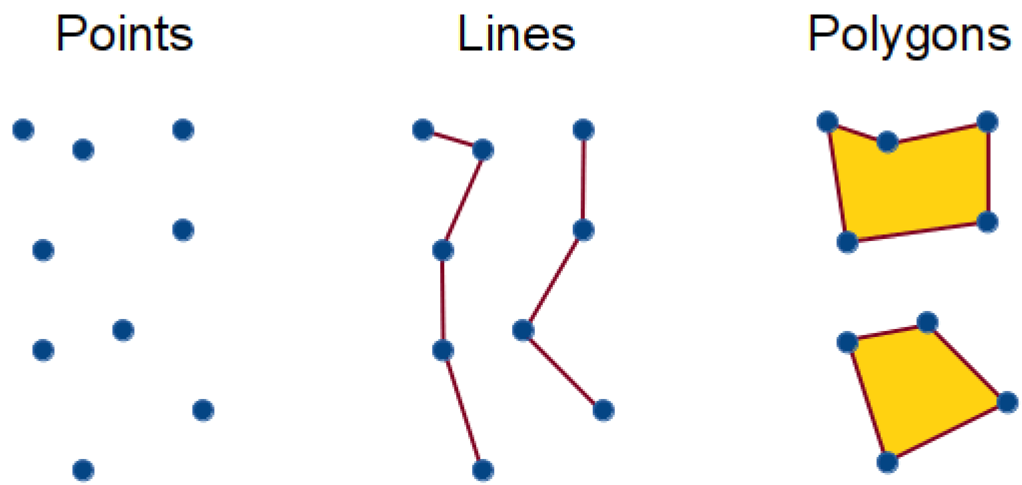


Figure 4: Points Polygon and Lines in GIS (**gitconnectedGeographicMicroservice?**)

> ❗ Important Reminder:
>
> The appropriate type of vector to use depends on the objector entity of interest.

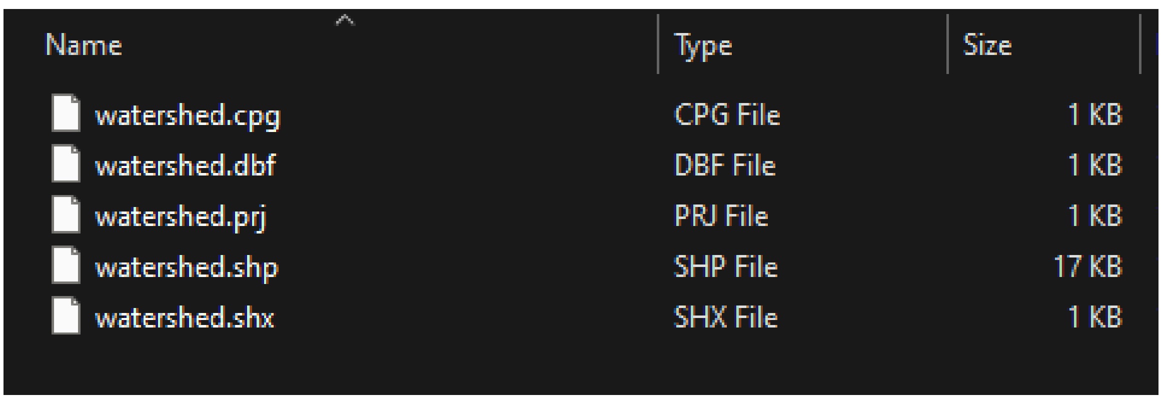


Figure 5: Shapefile has the same name but a different file extension.

1.4.6 The Shapefile

It is the most common supported vector file format. Despite the name, this is not a single file but a group of files sharing the same name but with different file extensions.

Table 3: The file extension and its description

File format	Description
.shp	• The main file. it could be either a point, line, or polygon.

File format	Description
.prj	• Contains the coordinate reference system.
.dbf	• The Excel file that holds the attribute data of the feature.
.shx	• The shape index makes it possible for users to seek backward in the shapefile.
.qml	• Customized layer style such as line color/thickness, color fill, etc.

1.4.7 File formats for Vector and Raster

Digital files come in various file formats, which can be identified by the suffixes following the "dot" (e.g. *.tiff). In the field of Geographic Information Systems (GIS), the following file types are the most common and widely accepted. The formats written in bold letters are the most popular file types used in GIS.

GIS Data Model	Common file format
Raster	• Arc/Info ASCII Grid • Arc/Info Binary Grid (.adf) • Windows Bitmap (.bmp) • Graphic Interchange Format(.gif) • TIFF/BigTIFF/GeoTIFF(.tif) • ERDAS Image (.img) • JPG, JFIF (.jpg) • JPEG2000 (.jp2,.j2k)
Vector	• AutoCAD (.dwg) • MapInfo TAB Format - *TAB, *.DATA, ID and MAP files • Keyhole Markup Language (.KML) • ESRI Shapefile (.shp), Shapefile (.shp)

! Important Note:

KML is a file that can be created, visualized, and edited using Google Earth application. SHP is the standard format for vector files and can be opened and read by almost any GIS software.

1.4.8 Examples of Vector and Raster

Below are some of the examples of vector and raster data. Note that this is not a comprehensive list.

Table 5: Examples of Vector and Raster

Data Model	Examples	Sample Products
Raster	• Satallite Images • Scanned maps • Arial Photograp • Digital elevation model • Digital Terrain Model • Digital Surface Model	• Landsat 4,5,7,7 (30m) • IKONOS images (2m) • NAMRIA • Arial Capture from Drone
Vector	• Shapefiles • KML • AutoCAD (DWG)	• Downloadable SHP from gadm.org • Google earth file • Schetch plans

1.4.9 Attributes

Every data, especially vector data, has an associated attribute table that holds information about that data. These could most easily be understood if the data is considered as a spreadsheet with one row per feature and one column.

Important Tips:

- Columns are also called **Fields**
- Rows are also called **Data/Records**

Vector data is usually linked with attributes, which can be modified by adding or removing fields, requiring the definition of their data type. The attribute's type will vary depending on the values expected to be stored in the cells of that field.

Rows are added when a feature or polygon is drawn from the QGIS map area.

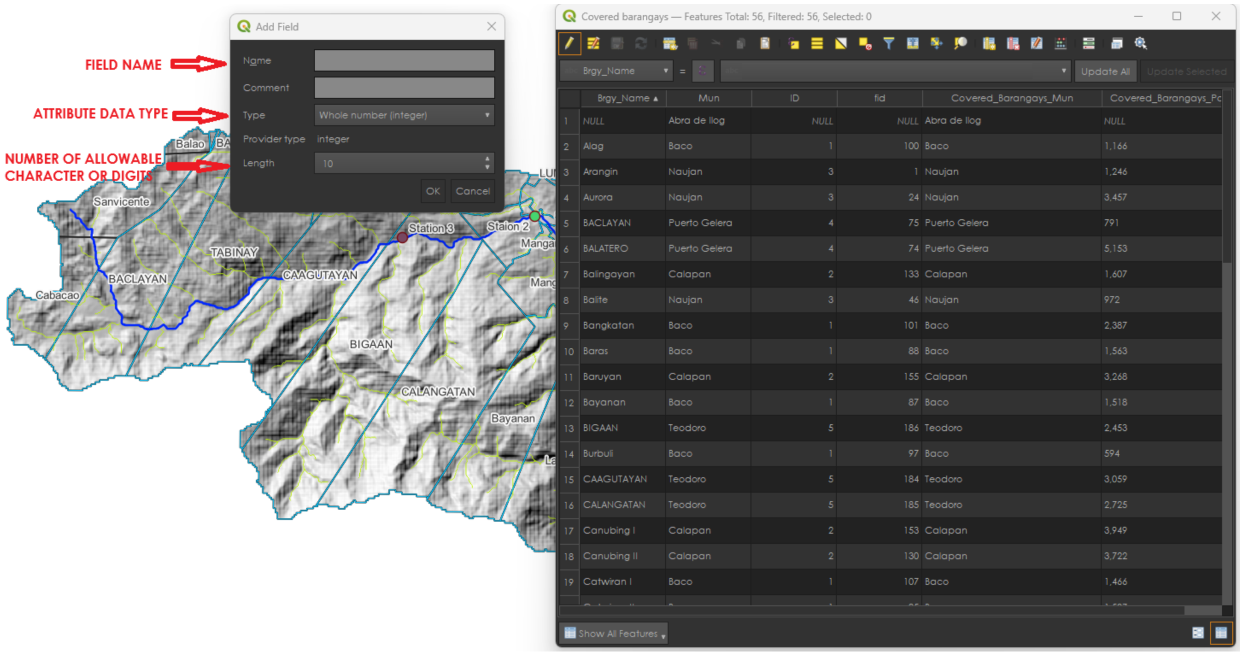


Figure 6: Attribute Table

1.4.10 Coordinate Reference System (CRS)

Do you still remember the Cartesian Coordinate System? This system allows us to locate the position of any point in space relative to an origin, which is the intersection of two perpendicular lines.

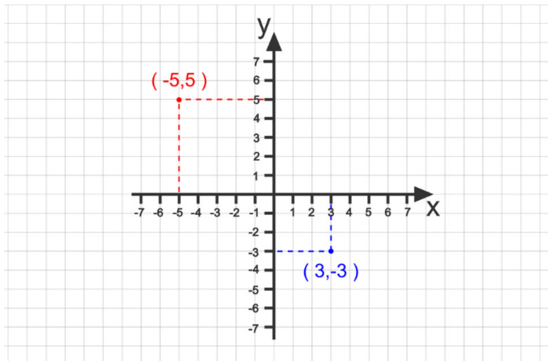


Figure 7: Sample of point plotting on a cartesian plane Russel (2019)

Important Tips:

The principles of the Cartesian Coordinate System is the same principle used in locating places on earth.

Any point on earth's surface can be represented by longitude and latitude instead of **X** and **Y** axes. The longtitude and latitude divided the earth vertically and horizontally in such a way that any given point could be NorthSouth or WestEast. Any point is relative to the Longtitude-Latitude intersection, which is the zero-degree Longtitude (**Prime Meridian)** and zero-degree Latitude (Equator).

1.4.11 Types of Coordinate Reference Systems (CRS)

There are two most commonly used coordinated reference systems in GIS. The Geographic Coordinate Systems (GCS) and the Projected coordinate systems (PCS). These two CRS display GIS data differently on a computer.

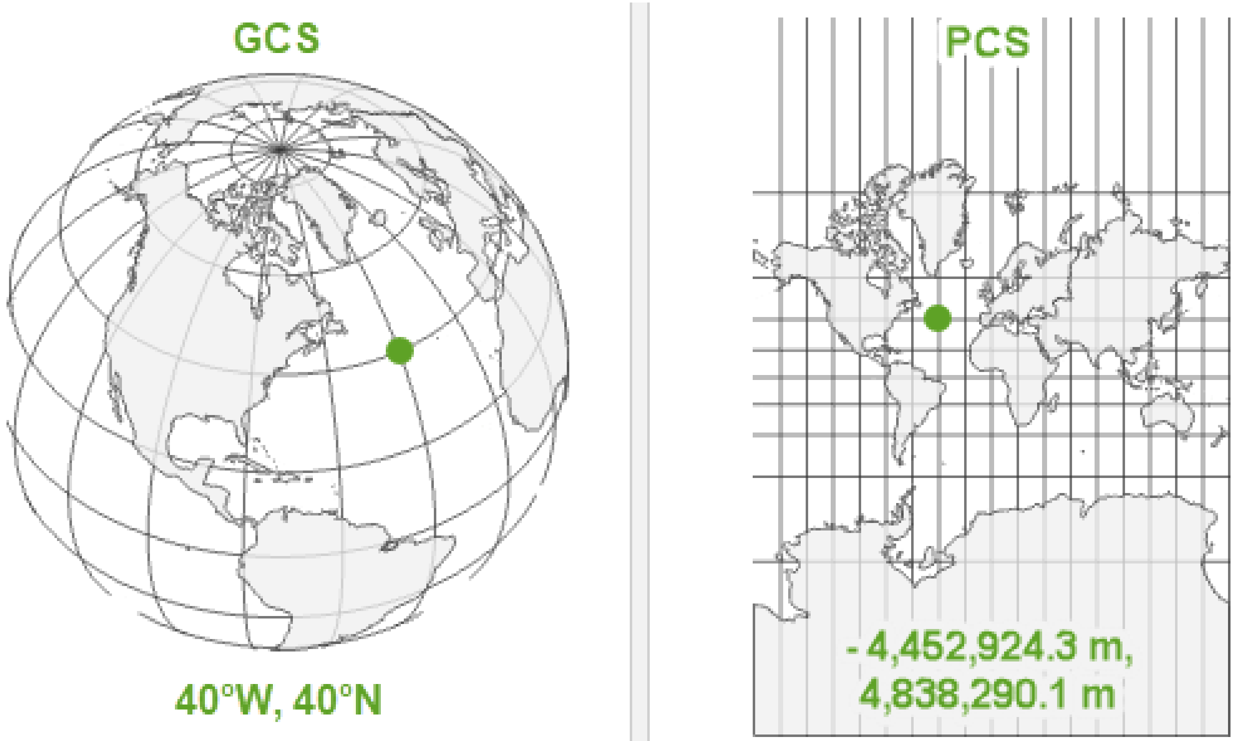


Figure 8: GCS vs PCS Buttery (2022)

The CRS, or Coordinate Reference System, is responsible for determining the units of measurement in a map, whether it's angular or linear. It also impacts the ability of map layers to overlay with one another. As a general rule, all data sets should have the same CRS to ensure proper alignment of the layers.

1.4.12 The Geographic Coordinate Systems (GCS)

The GCS uses the longitude latitude system and uses three-dimensional spherical surface to find locations and points since positions are based on angular distances everything is measured in degree units.

A location on Earth is defined by its coordinates, known as longitude and latitude. These coordinates are angles that originate from the Earth's center and extend to a specific point on the planet's surface. Typically, these angles are quantified in degrees or grads.

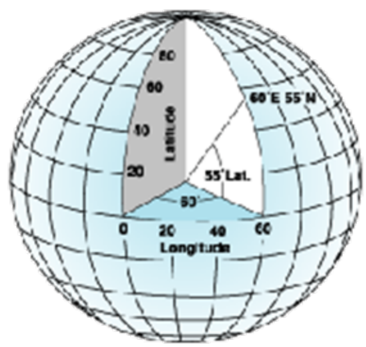


Figure 9: An illustration showing the world as a globe with longitude and latitude values

Within the spherical coordinate system, the horizontal or east-west running lines represent parallels, which are lines of constant latitude. Conversely, the vertical or north-south running lines signify meridians, which are lines of constant longitude. Together, these lines wrap around the Earth, creating a grid-like pattern known as a graticule.

The equator is the central line of latitude, equidistant from both poles, and is designated as the zero latitude line. The prime meridian, which is the zero longitude line, typically runs through Greenwich, England in most Geographic Coordinate Systems (GCSs). The point where the equator and the prime meridian intersect is known as the graticule's origin, with coordinates (0,0).

Latitude and longitude coordinates are conventionally expressed in decimal degrees or as degrees, minutes, and seconds (DMS). Latitudes are gauged from the equator, extending from -90° at the South Pole to +90° at the North Pole. Longitudes, on the other hand, are gauged from the prime meridian, spanning from -180° westward to 180° eastward. For instance, given that the prime meridian crosses Greenwich, England, Australia's position—south of the equator and east of Greenwich—results in positive longitude and negative latitude values.

Thinking of longitude as the 'x' value and latitude as the 'y' can be useful. When data is plotted on a geographic coordinate system, it's treated as though each degree is a fixed unit of measurement, akin to the Plate Carrée projection. It's important to note that a single physical location may be represented by different coordinate values across various geographic coordinate systems.

Important Tips

There are at least three ways to express GCS:

- Degrees-Minutes-Seconds
- Decimal minutes
- Decimal degrees

1.4.13 Projected Coordinate Systems

A **Projected Coordinate System (PCS)** is established on a plane, which is a flat, two-dimensional surface. In contrast to a **Geographic Coordinate System (GCS)**, a PCS maintains consistent lengths, angles, and areas throughout its two dimensions. A PCS invariably relies on an underlying GCS, which itself is derived from a spherical or spheroidal shape. Beyond the GCS, a PCS encompasses a map projection, which is further tailored for specific locations through a collection of projection parameters, and it also specifies a linear unit for measurement.

1.4.14 Geographic (datum) transformations

When dealing with two datasets that are aligned to different geographic coordinate systems, a geographic (datum) transformation may be necessary. This transformation is a precise mathematical process used to translate coordinates from one geographic coordinate system to another. Much like the coordinate systems themselves, there is an extensive array of predefined geographic transformations available for use. It's crucial to apply the correct geographic transformation when required, as failure to do so can result in coordinates being misplaced by as much as several hundred meters. In cases where a direct transformation is not available, it may be necessary to employ an intermediary GCS, such as the World Geodetic System 1984 (WGS84), and perform a combination of two transformations.

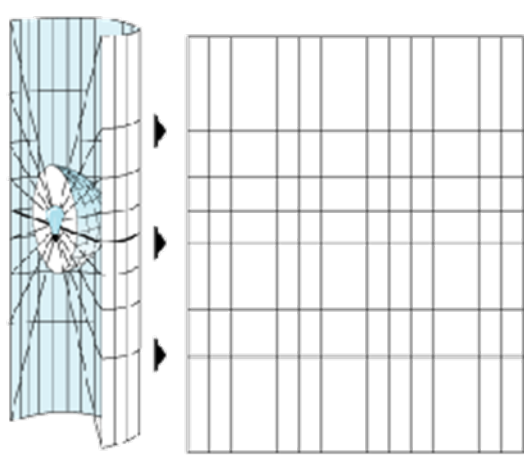


Figure 10: Projected

"Easting" refers to the measure of how far east a point is from the origin within a coordinate system, quantified in the units of that system. It corresponds to the **x-value** in a rectangular coordinate system. **"Northing,"** on the other hand, denotes the measure of how far north a point is from the origin, also measured in the system's units, aligning with the **y-value** in a rectangular coordinate system.

The world is divided into **60 longitudinal projection zones**, which are sequentially numbered from **1 to 60**, beginning at **180°W**. Each zone spans **6 degrees** in width, with certain exceptions in regions like Norway and Svalbard where the zones differ in width.

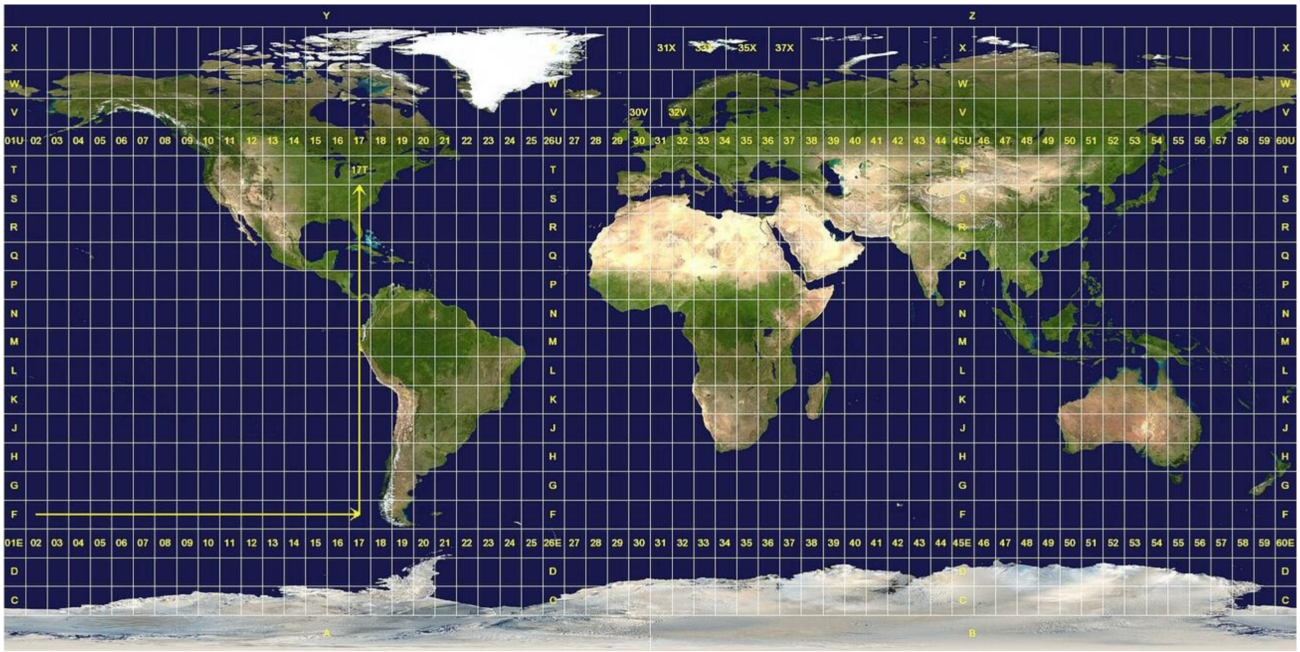


Figure 11: The Universal Traverse Mercator World Map Buttery (2022)

Comparison between PCS and GCS

A GCS is round, and so records locations in angular units (usually degrees). A PCS is flat, so it records locations in linear units (usually meters).

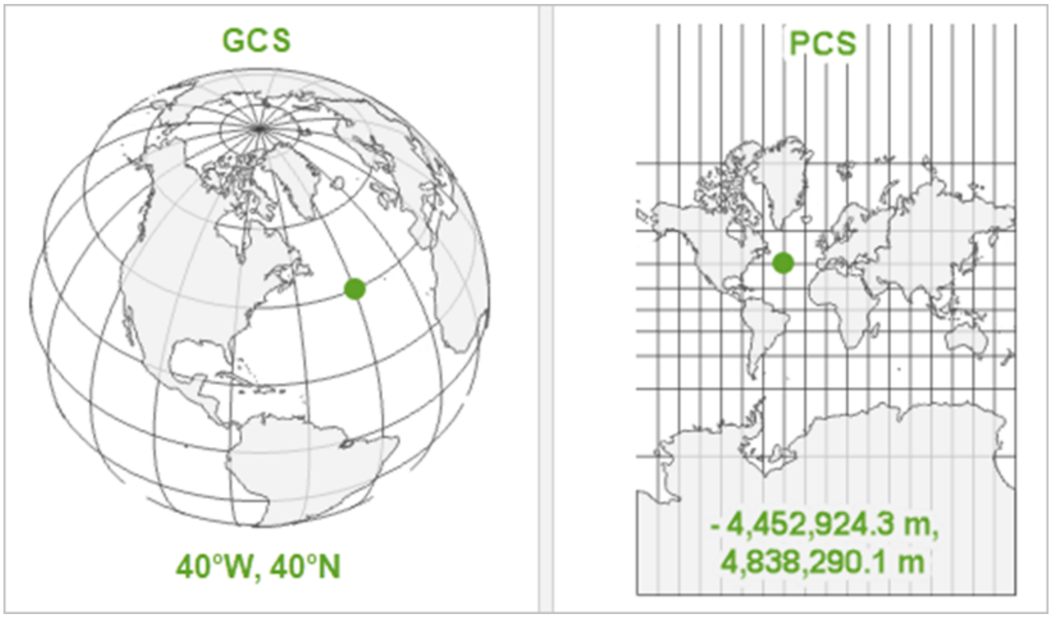


Figure 12: Comparison between PCS and GCS

Once your dataset is prepared to be depicted, it must determine the method of portrayal. The dilemma arises from the discrepancy between the spherical nature of the Earth's surface—and consequently, your **Geographic Coordinate System (GCS)**—and the planar characteristics of your map and computer display. Transferring the Earth's curvature onto a flat medium inevitably leads to distortion. It's akin to attempting to flatten an orange peel on a table; it nearly works, but not without some tearing. This is where the utility of map projections is evident. They provide instructions on how to manipulate the Earth's representation—how to strategically tear and stretch that orange peel—so that the most crucial aspects of your map suffer minimal distortion and are optimally represented on the map's flat plane.

2 MODULE 2: INTRODUCTION TO QGIS (Installation, User-Interface, and Plugins)

2.0.1 Objectives:

This module enables the students to :

1. Have an overview on what is QGIS and ,
2. Familiarize its user interface.

2.0.2 Outcomes

After reading and following the steps and procedure in this module, the students should be able to:

1. Install QGIS in their computer successfully,
2. Familiarized its user interface, able to identify useful geoprocessing icons and,
3. Install plug-ins.

Definition of terms

2.1 Overview of the QGIS Software

2.1.1 What is QGIS?

QGIS is a sophisticated GIS application that not only stands on the shoulders of Free and Open Source Software (FOSS) but also takes pride in being part of the FOSS community.

QGIS is an accessible and open-source Geographic Information System (GIS), licensed under the GNU General Public License. As an esteemed project of the Open Source Geo-spatial Foundation (OSGeo), it operates across various platforms including Linux, Unix, Mac OSX, Windows, and Android, and accommodates a wide array of vector, raster, and database formats and capabilities.

2.1.2 QGIS Applications

QGIS is not only a desktop GIS. It can also be used for spatial file browser, a server application, and web applications. Below are some of the applications of QGIS.

Table 6: QGIS Applications "QGIS Application"

Application	Description
QGIS Desktop	Create, edit, visualise, analyse and publish geospatial information. For Windows, Mac, Linux, BSD and Android.
QGIS Server	Publish QGIS projects and layers as OGC compatible WMS, WMTS, WFS and WCS services. Control which layers, attributes, layouts and coordinate systems are exported. QGIS server is considered as a reference implementation for WMS 1.3.
QGIS Web Client	Publish QGIS projects on the web with ease. Benefit from the powerful symbology, labeling and blending features to impress with your maps.
QGIS on mobiles and tablets	The QGIS experience does not stop on the desktop. Various third-party touch optimized apps allow you to take QGIS into the field

2.1.3 Software Installation

The following steps shows you how to install QGIS into your computer. In order to install the QGIS software you need to download the software first.

Step 1. In your internet browser type https://qgis.org/en/site/index.html in the search bar. The official website of QGIS will appear.

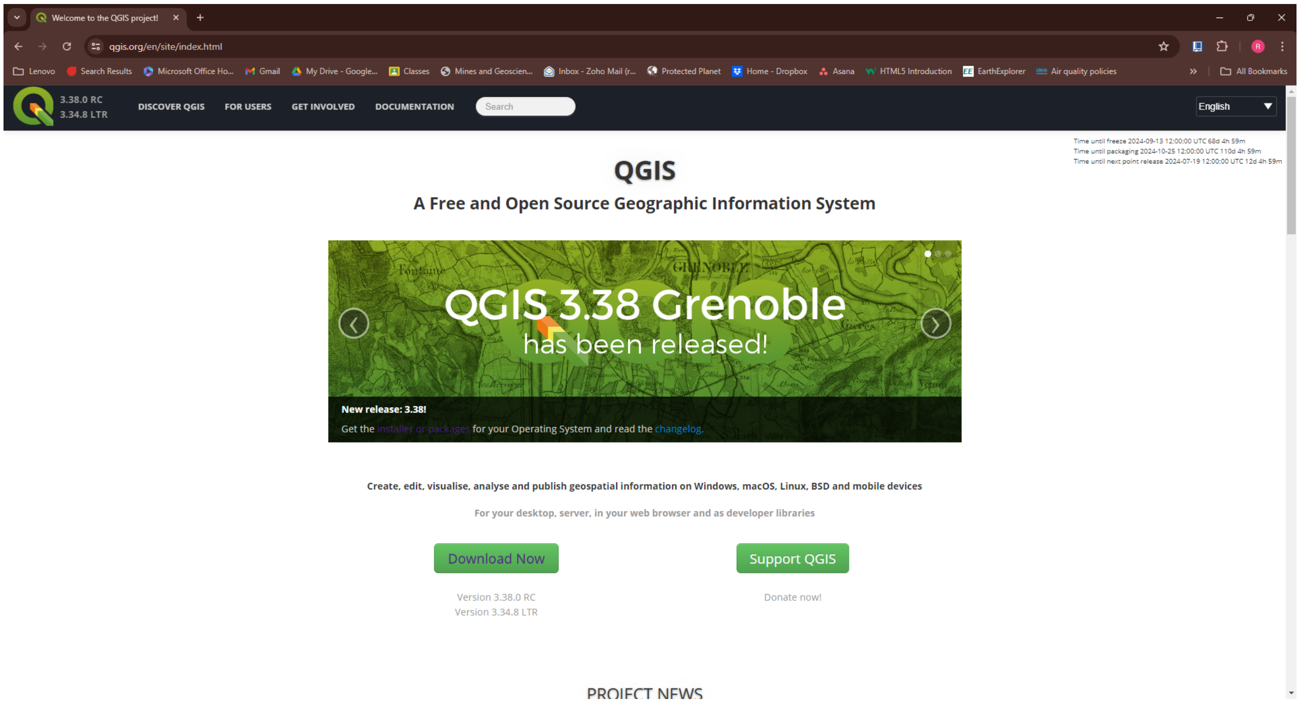


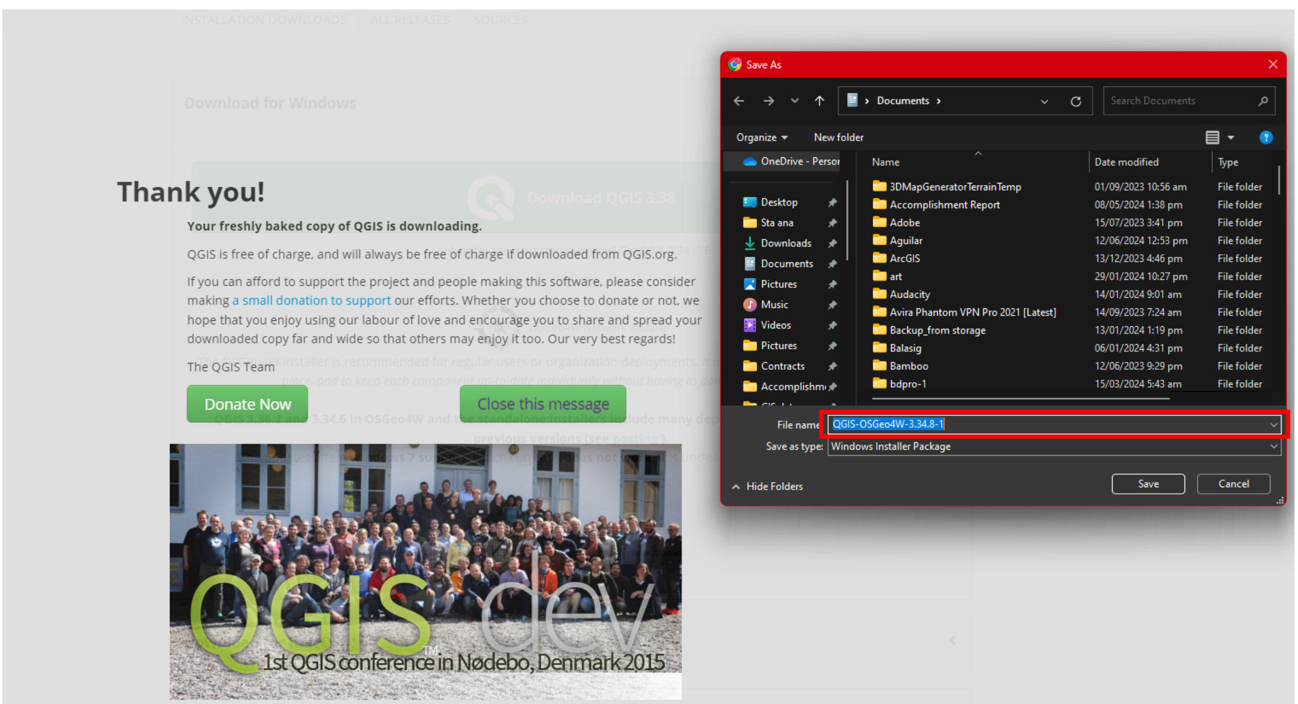
Figure 13: QGIS official Website

Step 2. In the web page, you can see two buttons the Download Now and Support QGIS. You can also observe that under the Download Now are two versions the Release Candidate (RC) and the Long term release (LTR). Click the Download Now to proceed to the download page.

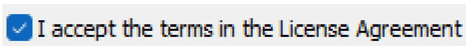
> **Tip**
>
> **Release Candidate (RC)** is the latest version of QGIS that is being tested and can be used. The only disadvantage of this version is that it is prone to Bugs and frequent Crash. While **Long Term Release (LTR)** is usually older version of the software that is more stable that the release candidate.

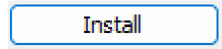
Step 3. The download page will appear showing a large download button. Click the Get QGIS 3.34 LTR link below the button since it is better to download the long term release version of the software.

Step 4. A dialog box will appear asking you where to put the downloaded file. Choose a folder then click Save button to download the software. Wait until the software is downloaded. This may take some time depending on the size of the file being downloaded and how fast your internet connectivity.

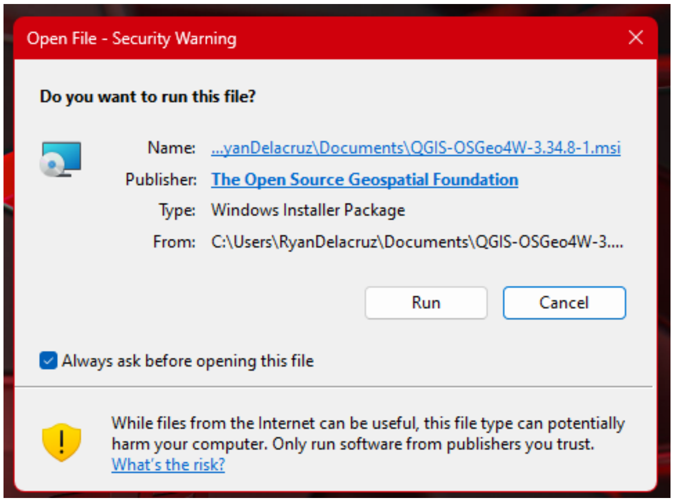


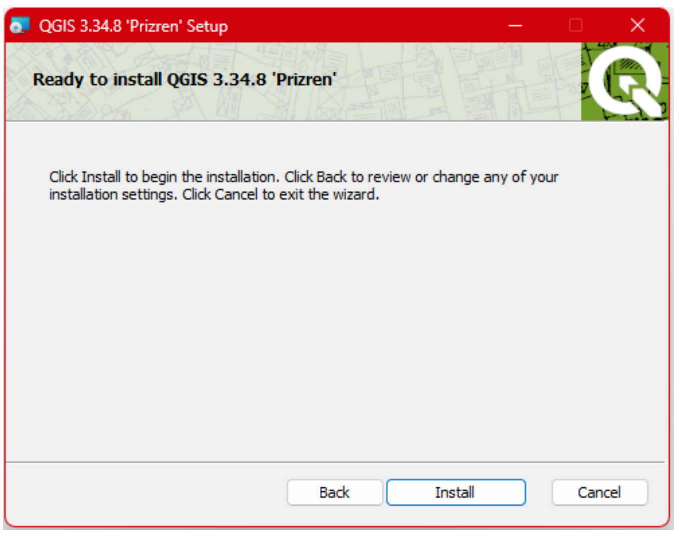
Step 5. Double click the file that you have downloaded and a dialog box will appear. Click Run and another dialog box will appear. Just click Next and tick the



lastly , hit 

. Wait Until the software is successfully installed.

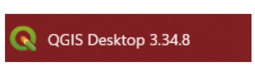




2.1.4 QGIS Graphical User Interface (GUI)

After installing the software, click the windows icon ( windows icon) and look for the recently installed application or type QGIS Desktop 3.34.8 on search bar (

search bar).

Step 1. Click 

to open the software. The QGIS interface will show up showing your recent project if you have already used it but usually this will be blank if you are using it for the first time.

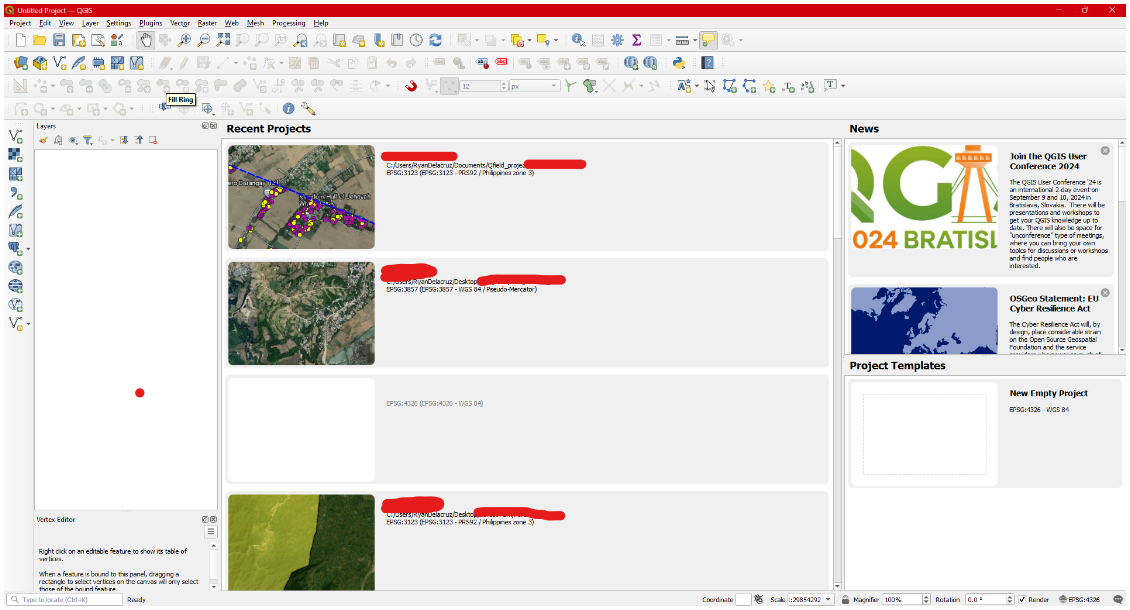
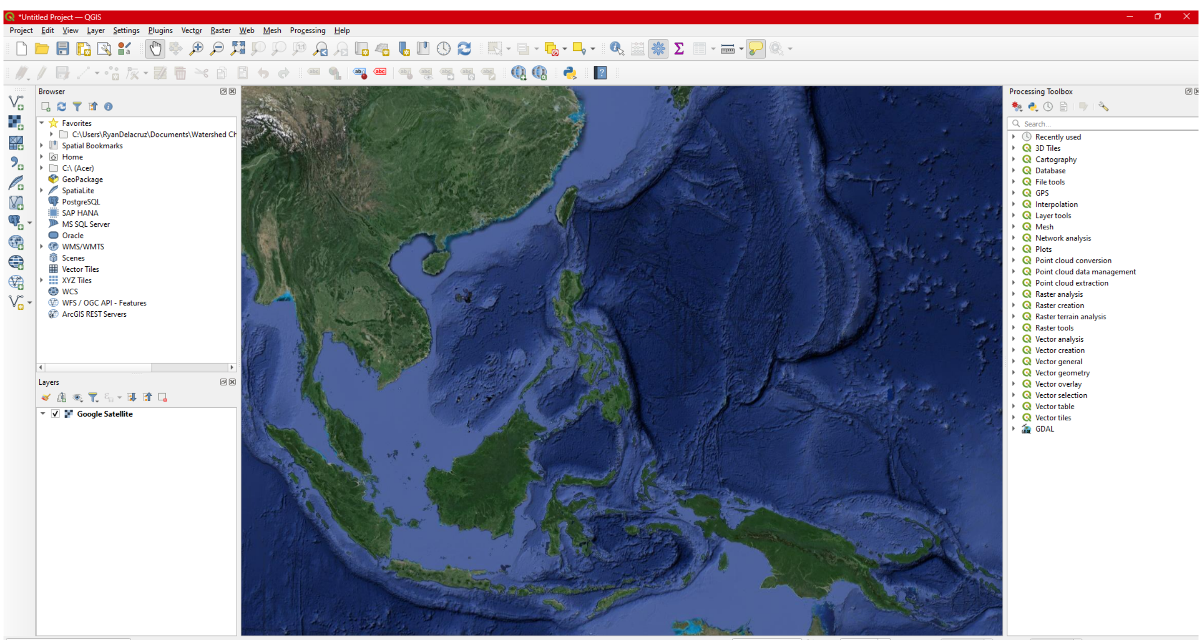
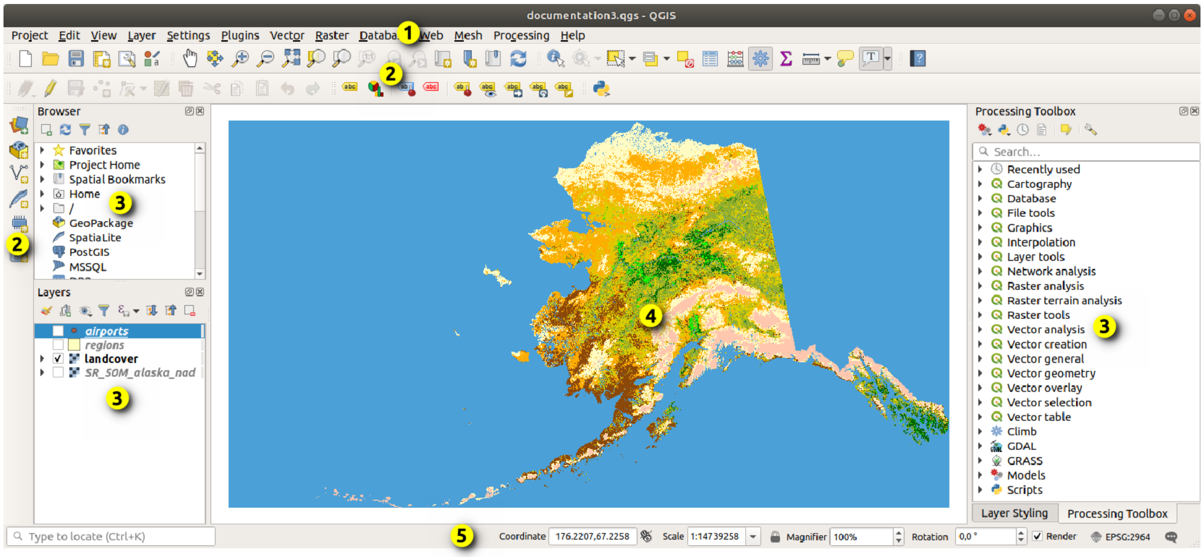


Figure 14: QGIS user interface

Step 2. Press **Ctrl + N** to start a new project or Click the  **New Project** icon. An new untitled project was just created.



The graphical user interface (GUI) of QGIS is depicted in the figure below. The yellow circles labeled with numbers 1 through 5 highlight essential elements within the QGIS GUI, which will be explained further.


documentation3.qgs - QGIS
Project Edit View Layer Settings Plugins Vector Raster Database Web Mesh Processing Help
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Project Home
Spatial Bookmarks
Home
/
GeoPackage
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PostGIS
MSSQL
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Layers
airports
regions
landcover
SR_50M_alaska_nad
3
4
Processing Toolbox
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Recently used
Cartography
Database
File tools
Graphics
Interpolation
Layer tools
Network analysis
Raster analysis
Raster terrain analysis
Raster tools
Vector analysis
Vector creation
Vector general
Vector geometry
Vector overlay
Vector selection
Vector table
Climb
GDAL
GRASS
Models
Scripts
3
Layer Styling
Processing Toolbox
Type to locate (Ctrl+K)
5
Coordinate 176.2207,67.2258
Scale 1:14739258
Magnifier 100%
Rotation 0,0 °
Render
EPSG:2964

References

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