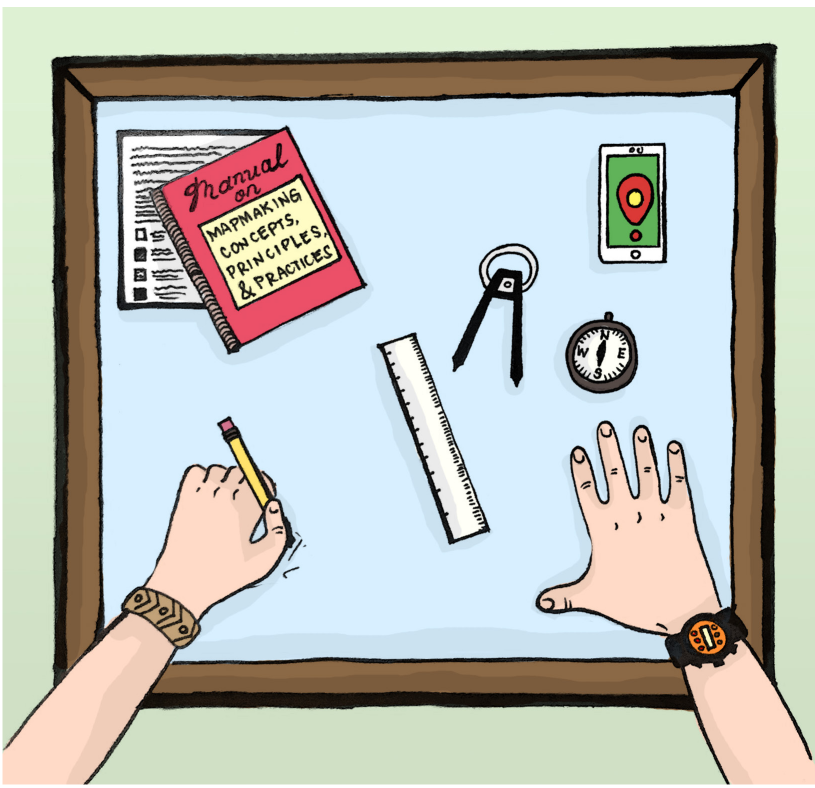
# CHAPTER 1: MAPMAKING CONCEPTS, PRINCIPLES, and PRACTICES



# CHAPTER 1: MAPMAKING CONCEPTS, PRINCIPLES, and PRACTICES

Cartography is the science and art of map-making. Science because it concerns with the discovery and organization of knowledge using information system technologies such as Geographic Information System (GIS) which has the capability for capturing, managing, manipulating, and visualizing geographic information. It is an art because mapmaking requires imagination, creativity and innovation.

A map is a graphic representation or scale model of spatial concepts. It is a means for conveying geographic information easily understood by people, regardless of language or culture. A map is a powerful tool to visualize the situation. It helps us to locate where the problematic areas are and provide useful information as basis for policy formulation and development interventions that are tailor-fitted to the needs of the local people.

Map makers must learn the basic elements of a map, understand the planning process, and possess skills designing and production based on cartographic principles and participatory geographic information system (PGIS) tools.

| ELEMENTS OF A MAP | PREPARATION OF MAPMAKING AND CODE OF ETHICS |
|---|---|
| •Title<br>•Orientation<br>•Legend<br>•Reference System<br>•Vicinity Map<br>•Publication<br>•Citations | •Context<br>•Target audience<br>•Cartographic standard<br>•Common practice and code of ethics |
| **MAP DESIGNING** | **MAP PRODUCTION** |
| •Geographic Reference System<br>•Map Projections<br>•Map Scale<br>•Design Principles & Rules | • GPS Gamin Receiver<br>• Quantum GIS Application<br>• Individual Exercises<br>1. Data Capture& Saving<br>2. Closing CLOA<br>3. Map Overlay |

**Figure 1. Basic knowledge and skills in mapmaking.**

## ELEMENTS OF A MAP

A map has the following cartographic elements as shown in red boxes in Figure 2:

- Title – clearly state what the map shows and where the map is located
- Orientation – must show North arrow
- Legend – be precise and clearly define categories and meaningful symbols
- Reference System – Datum + Projection + Coordinate System
- Scale – represents the ratio of the distance between the points on the Earth and the distance between the two corresponding points on the map

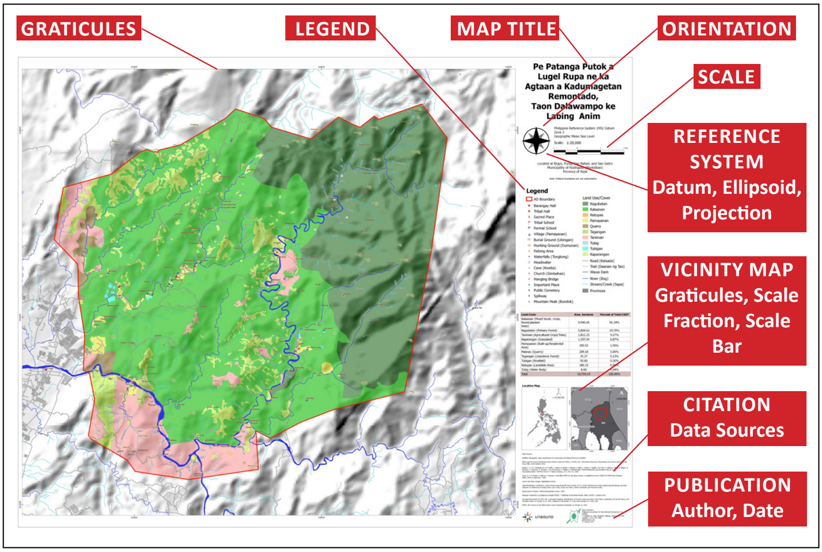



**Figure 2. Cartographic elements of a map.**

- Vicinity Map – indicating Graticules, Scale Fraction and Scale Bar
- Citations – indicating data sources both geographic and attribute data
- Publication – citing the author and date of map publication

## PREPARATION FOR MAPMAKING

In preparation for making a map, it is important to consider the following factors, namely: (a) context, (b) target audience, (c) cartographic standard and common practice, and (d) cartographic code of ethics.

**Context:** Maps are made according to purpose and depending on the people's needs, issues, and concerns. For land rights advocates, the purpose and content may be influenced by community context which usually revolves around land tenure issues and resources for IPs as shown in Figure 3.

| LAND TERRITORIES AND RESOURCES | |
|---|---|
| Increase and decrease in land areas  | • According to land use |
| | • According to customary land tenure |
| Land tenure   | • Percentage of people with customary land tenure |
| | • No. of people benefitting |
| | • With customary land tenure recognized by state |
| | • Those not recognized by state |
| Conflict  | • Areas of conflicts<br>• Areas under control of state or corporations |
| | • Areas claimed by state but can be used by indigenous peoples |
| Laws enacted affecting traditional land-use and land tenure and their effects | • No. of communities or percentage of population affected<br>• Lands converted to different land use |
| Statutory and/or indigenous peoples' intervention on disaster prone areas | • Increase or decrease of land areas prone to disaster |
| State policies   | • Increase or decrease in percentage of forest protected by state and/or indigenous peoples |
| | • Percentage or number of law passed/implemented recognizing the customary rights of people to their forest and its management |
| Water  | • Decrease or increase in number of water sources, water volume, quality, and portability of water for community use. |
| | • Incidences of water-related violence and tensions |
| | • List of flora and fauna of different uses and assessment on trends from historical information. |
| Trends and changes in access to indigenous medicine |  |

**Figure 3. Land tenure issues and resources for indigenous peoples.**
*Adapted from CBMIS for Community Trainers and Organizers, TEBTEBBA Foundation*

**Target audience:** The users will influence how a map should appear, both in content/substance and format. Target audience may include, among others, IP communities, government officials, and local executives.

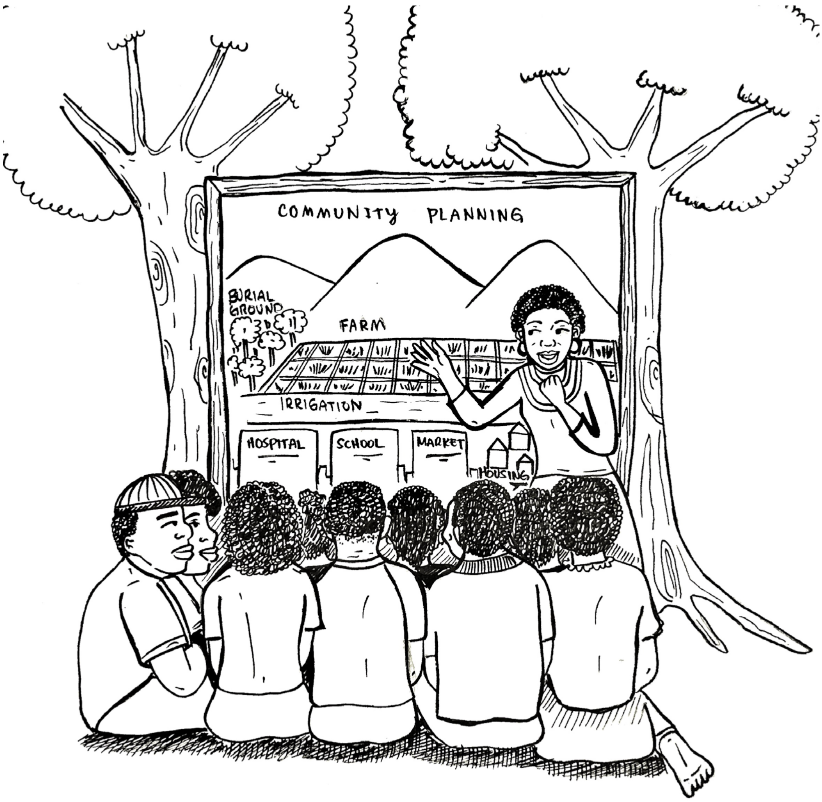



**Figure 4. Indigenous peoples as the target audience of the map.**

Participatory mapping can be used as a strategy for awareness raising, education and community organizing. The map can strengthen community's arguments for land rights advocacy during dialogue and negotiations with government officials and other stakeholders.


**Figure 5. Participatory maps used as advocacy material during dialogues with government.**

Participatory mapping can be used for visualization and the development of Ancestral Domain Sustainable Development Protection Plan (ADSDPP) for indigenous communities.

With the objectives in mind, the appropriate methodology that can be identified is PGIS Mapping through 3-D Modelling techniques combined with GIS Technology.


**Figure 6. Participatory mapping as a tool for visualization and development of the indigenous community's ADSDPP.**

## Cartographic standards common practice:

a. Generalization is the process of reducing certain details in a map in a meaningful way. Maps contain a certain level of detail depending upon its scale and purpose. It is important that geometric and attribute accuracy as well as the presentation quality of the map must be maintained.

b. Graphic Variables refer to the different graphic characters or symbols that may render different perceptions to the map readers which can affect the map design in terms of choosing Font Size, Value, Texture, Color, Orientation, and Shape.

c. Methods and Types of Map-users will influence the way maps will be projected. Basically, there are three types of maps: (1) General Purpose Maps, (2) Thematic Maps, and (3) Topographic Maps.

**Cartographic Code of Ethics:**

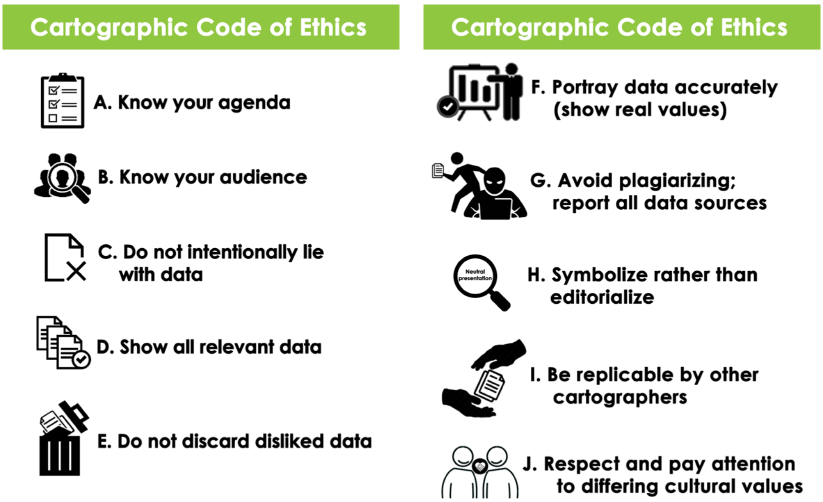



**Figure 7. Cartographic code of ethics.**
*Source: Dodge, M., Cartographic Principle: Map Design*

# MAP PRODUCTION

## *Spatial Data Collection*

Map production starts with data collection from their source either a questionnaire or input from an electronic device.

Data capture is the conversion of geographic coordinate data (through field survey using Global Navigation Satellite System (GNNS) device or smartphones with GPS capability) into a computer-readable format.

## *What is GPS and GNSS?*

The wider application of GIS has been accompanied by the development of enabling technologies such as the Global Positioning System (GPS), a satellite-based navigation system made up of a network of satellites that orbit the Earth and send a signal to GPS receivers such as the Garmin Oregon 650, giving a precise location, speed and altitude.

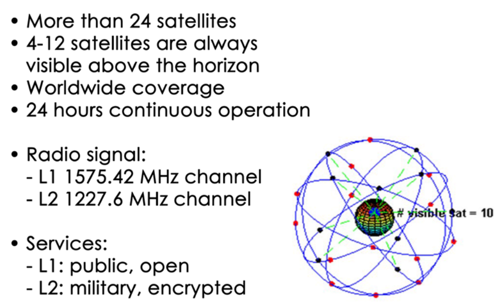



**Figure 8. Network of satellites orbiting the Earth.**
*Source: PAFID (Zingapan, K., 2017)*

**Figure 9. Global position system receivers.**

Since 1983, GPS technology has revolutionized field mapping. Inexpensive GPS receivers can provide reasonably accurate information about the latitude, longitude and altitude of the user's position at anytime and anywhere in the world. GPS methods have been integrated in many applications areas such as forestry, geology and community development. GPS technology has been widely used worldwide for community mapping, useful for land use planning, and management of natural resources.

Today, the GPS system provides critical positioning capabilities to military, civilians and commercial users. The US government created the system, maintains it, and makes it freely accessible to anyone with a GPS receiver.

Incidentally, the Global Navigation Satellite System (GNSS) was developed by other nations for military services and civilians. The GNSS is essentially a satellite system used to pinpoint the geographic location of a user's receiver across the globe. Hence, there are now more satellites available and enabling positions to be fixed more quickly and accurately other than the GPS developed by the US military.

At present, there are at least six GNSS systems currently in operation. These are the: i) US Global Positioning System (GPS); (ii) Russian Federation's Global Orbiting Navigation Satellite System (GLONASS); (iii) Europe's Galileo; (iv) China's BeiDou Navigation Satellite System now known as Compass; (v) India's Global Indian Navigation System (GINS), and (vi) Japan's Quasi-Zenith Satellite System (QZSS).


**Figure 10. Global Navigation Satellite System.**
*Source: PAFID (Zingapan, K., 2017)*

Each of the GNSS system employs a constellation of orbiting satellites working in conjunction with a network of ground stations. GNSS precision varies depending on what particular technologies are being used.

## How a typical hand-held GPS works

1. GPS is based on triangulation from satellites. The GPS adhere to the principle of *triangulation* to locate the user through calculations involving information from a number of satellites. Each satellite transmits coded signals at precise intervals. The receiver converts signal information into position, velocity, and time estimates.

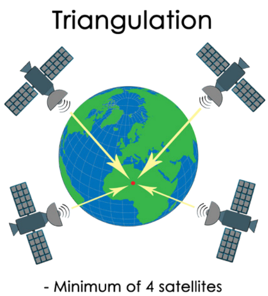



**Figure 11. Triangulation of satellites.**

2. GPS receivers measure distance from satellite using travel time of radio signals.

3. To measure travel time, GPS needs precision and accurate timing.

4. Along with distance, the receiver must know exactly where the satellites are in space. Satellite location, high orbits and careful monitoring are the key to get accurate location expressed in Latitude and Longitude.

5. Users must correct any delays the signal experiences as it travels through the atmosphere. A Satellite-Based Augmentation Systems (SBAS) can transmit corrections and integrity data for GPS/GNSS system to improve accuracy to 15 meters.

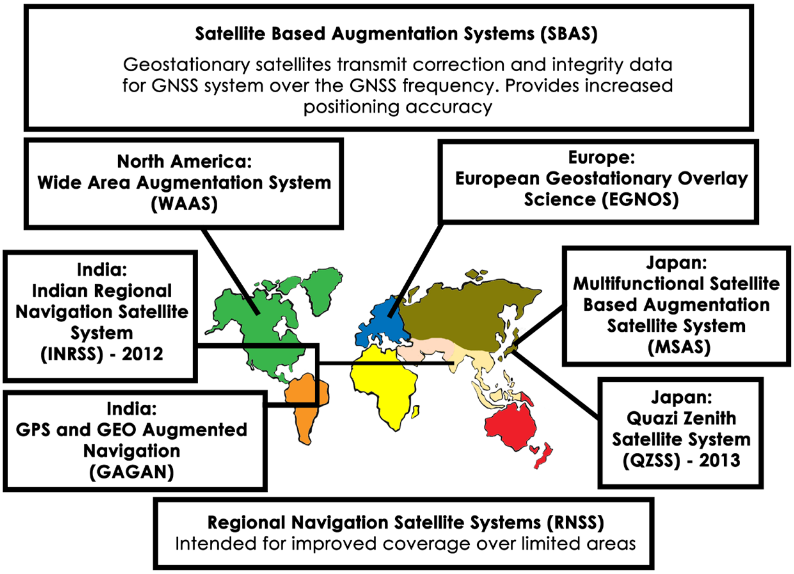



**Figure 12. Satellite-based Augmentation Systems.**

## GPS/GNSS Data Capture using Garmin GPS Receiver: An Example

1. Turn-on the GPS Garmin receiver.
2. The datums and grid preferences can be reached from the main menu by selecting the navigation setup options.
3. Set the navigation datum, the navigation grid, and the user units.
   - For GPS navigation and geophysical use, a datum (such as WGS 84) which is a model of the Earth is used as reference point from which the receiver can measure things.
   - The GPS defines a three-dimensional model that “describes mathematically the shape of the Earth, the location of the center and the location on the surface that represents the starting point for measuring” (DePriest, 2013).
4. In the Application Drawer, select the Satellite icon to open the Satellite Page and wait for the GPS receiver to acquire four or more satellites. Once it finds a position lock, the display will change to show a location (expressed

in degrees Longitude and degrees Latitude), an accuracy estimate, and an elevation.

Once the GPS has a position lock, numbers appear on the top pane of the satellite page (see Figure 13).

- The string of numbers on the top left corner is the GPS measurement for the Latitude of the location, expressed in degrees-minutes-seconds.
- The series of numbers below the Latitude is the GPS measurement for Longitude of the location, also expressed in degrees-minutes-seconds.

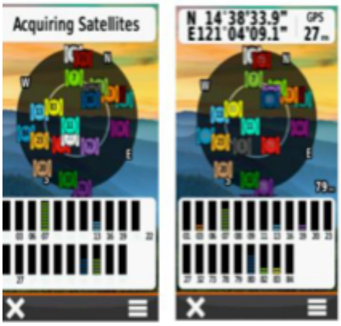


**Figure 13. GPS receiver screen showing the satellite page.**

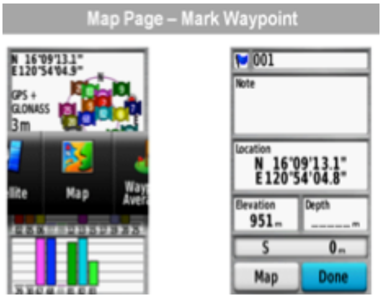


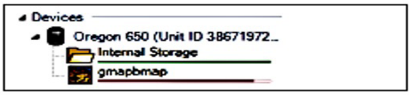
**Figure 14. GPS receiver screen showing GPS measurements.**

5. The number on the upper right corner is an accuracy assessment of the GPS measurement. The number indicates the size of a circle (radius) inside of which the true position lies. A smaller circle indicates a more accurate measurement. Good survey conditions will give an accuracy of 10 meters or less. If possible, wait until the number for GPS accuracy falls to 10 meters or lower before starting the data capture.
6. Capturing locational information in the field is usually done using Waypoints. Mark your waypoints in the Waypoints Page of the GPS receiver, assign a unique name, and click Done.
7. Repeat steps 4 to 6 whenever a data will be captured in specific locations until all spatial data are generated.

## How to download, view and save GPS/GNSS data

**Download GPS Data to Computer**

1. Plug the GPS receiver in a USB port on the computer
2. Open Garmin in BaseCamp
3. In the left-hand panel under Devices, select the folder named Internal Storage
4. In the left-hand pane; under Internal Storage, look for the GPS waypoints and tracks you wish to export.
   - Use the Pan and Zoom buttons to move around the map view
   - To select, click on the Select button and draw a box surrounding all waypoints and tracks you wish to export
   - For multiple selections, hold down the Ctrl key and click on the names of the GPS waypoints and tracks to be exported




**Export as a Garmin GDB file as backup copy of your GPS survey**

5. Click on File> Export> Export Selection
   - Select a folder to store your GPS data
   - In the panel for File name, type a name for your survey data
   - In save as type, ensure that Garmin GPS Database Files (*.gdb) is selected
   - Click on Save

**Export as a GPS exchange Format (*.gpx) file for viewing in Quantum GIS**

6. Ensure that the waypoints and tracks to be exported are still selected
   - Click on File> Export> Export Selection
   - Select the folder for your GPS data archive
   - In the panel for File name, type a name for your survey data
   - In Save as type, ensure that GPS exchange Format (*.gpx) is selected
   - Click on Save

**Export as a KML 2.2 Document v2 [*.kml] to view your survey in Google Earth**

7. Ensure that the waypoints and tracks to be exported are still selected
   - Click on File> Export> Export Selection

- Select the folder for your GPS data archive
- In the panel for File name, type a name for your survey data
- In Save as type, ensure that KML 2.2 Document, v2 (*.kml) is selected
- Click on save

8. If you wish to export all data inside the GPS receiver, click on File> Export> Internal Storage

**View GPS Data in Garmin BaseCamp and Google Earth**

9. In the left-hand panel under Internal Storage, right-click on the GPS data you wish to view
    - Select Show on Map
    - Use the mouse wheel to zoom in and zoom out of the map
    - Use the Navigation buttons  to pan, zoom and select on the map shown
10. In the left-hand panel for Internal Storage, right-click on the GPS data you wish to view
11. Select Open
    - This opens the Properties Page which shows the data for each GPS feature
12. Open Google Earth
    - Ensure that the computer is connected to the Internet
    - In Google Earth, click on File> Open and browse to the folder of your GPS data archive
    - Select the KML file for your GPS survey
    - Use the mouse wheel to zoom in and zoom out of the map. Press and hold the Shift key to rotate the view. Press and hold the Ctrl key to tilt the view and show the elevation profile.
    - To reset the view, type ‘R’ on the keyboard.

## MAP DESIGNING

If *Cartography* is the science and art of mapmaking, *Geodesy i*s the science of accurately measuring and understanding the Earth’s geometric shape, orientation in space, and gravity field. In map designing, the users must bear in mind the following principles as shown in Figure 15.

| 1. GEOGRAPHIC REFERENCE SYSTEM | 2. MAP PROJECTION |
|---|---|
| • Maps have a reference grid or coordinate system<br>• Maps have a reference starting point or datum. | • Maps are a flat model of a spherical Earth<br>• Objects of the Earth's surface are distorted when a map is projected on a flat surface. |
| **3. MAP SCALE** | **4. DESIGN PRINCIPLES AND RULES** |
| • Maps have strong bearing on GIS analysis<br>• Maps Scale have 3 types:<br>1. Fractional Scale<br>2. Graphic Scale<br>3. Verbal Scale | • Simplicity<br>• Proximity<br>• Alignment<br>• Repetition<br>• Contrast |

**Figure 15. Principles of map designing.**

## 1. Geographic Reference System (GRS)

- The first important spatial concept in mapping technology is to communicate and locate objects using spatial reference system which has the following characteristics: (a) stability, (b) the ability to show points, lines and areas, and (c) the ability to measure length, size and shape (Dale and McLaughlin, 1988).
- GRS has three categories namely: (a) geographical coordinate system, (b) rectangular system, and (c) non-coordinate system.

  a. **Geographic coordinate systems –** the coordinates of any location on the Earth surface can be defined by latitude and longitude. Lines of longitude, commonly called meridians, are drawn from pole to pole as shown in Figure 16.

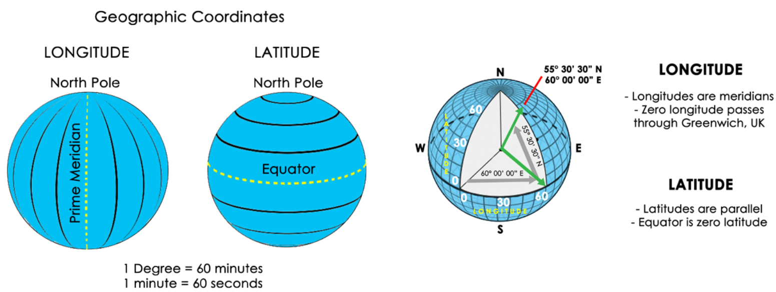



**Figure 16. Geographic coordinates system.**
*Source: PAFID (Zingapan, K., 2017)*

The starting point for these lines is called the *prime meridian* that runs through Greenwich, England.

Greenwich meridian – the longitude of reference, i.e., 0° east or west. It passes through the English town of Greenwich, a suburb of London. Basically, the prime meridian is the starting or zero point for angular measurements, east and west. The lines of latitude lie at right angles to lines of longitude, and run parallel to one another. That is, each line of latitude represents the circle rounding the globe.

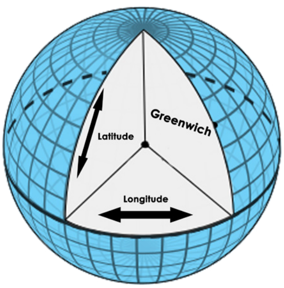



**Figure 17. Greenwich meridian.**
*Source: Geographic Grid (M. Anji Reddy, 2008)*

b. **Rectangular coordinate systems –** most of the spatial data available using GIS are in two-dimensional form. This coordinate referencing system to locate any object point is called rectangular coordinate system.

c. **Non-coordinate systems** – this GRS provides spatial references using a descriptive code rather than a coordinate, such as, postal codes, which are numeric in nature (e.g. UK and Canada postal codes).

- Maps have a reference starting point otherwise known as a datum.
- Datums are based on a model of the Earth called a reference ellipsoid and enable all the various

projections in a GIS work together to give an accurate picture of the Earth.

- Datums are a reference surface that is defined by:
  i. Ellipsoid – described by its origin and coordinate system
  ii. Survey – a survey of points and lines tying the ellipsoid to point on Earth (e.g. WGS 1984 Datum; Luzon 1911 Datum; Everest 1830 Datum)
- Maps have a reference grid — a geographic data model that represents information as an array of uniform square cells.
- Each grid cell has a numeric value that refers to the actual value of a geographic phenomenon at that location (e.g., population density or temperature) or it indicates a class or category (e.g., the enumeration area identifier or soil type).
- The reference grid helps the user navigate the map and links the spherical earth to the map projection.
- GIS is grid-based technology with the following functionalities as shown in Table 1.

**Table 1. GIS functionalities.**

| Function Type | Where it operates | What it is used for |
|---|---|---|
| Local | On individual grid cells | To change cell values based on user definition or the value of corresponding grid cells on other layers. |
| Focal | On a specifically targeted grid cell | To return a value (such as an average) based on the values of neighbouring grid cells. |
| Zonal | On grid cells in specifically identified regions | To calculate values based on analysis of specified regions that are not necessarily connected. |
| Block | On square blocks of grid cells | To return a value for the identified block (for example, a 4x4 block of cells) on an output grid |
| Global | On the entire grid | To highlight hard-to-find features and spot general trends by moving through the entire grid |
| Specialty | On specified grid cells | To perform high-end statistical analysis or create models for moving surfaces (such as water or pollution) |

*Source: DeMers, M., GIS for Dummies*

2. **Map Projection**

- Maps are a flat model of a spherical Earth as shown in Figure 18.
- In principle, objects of the Earth's surface are distorted when a map is projected on a flat surface either in size, shape or in relative location (Maling, 1980)
- The globe is in 3D and a flat surface is in 2D. All 2D maps have some "distortion".
- Distortions of areas could lead to incorrect measurements. Hence, map projections are needed so that areas can be preserved.

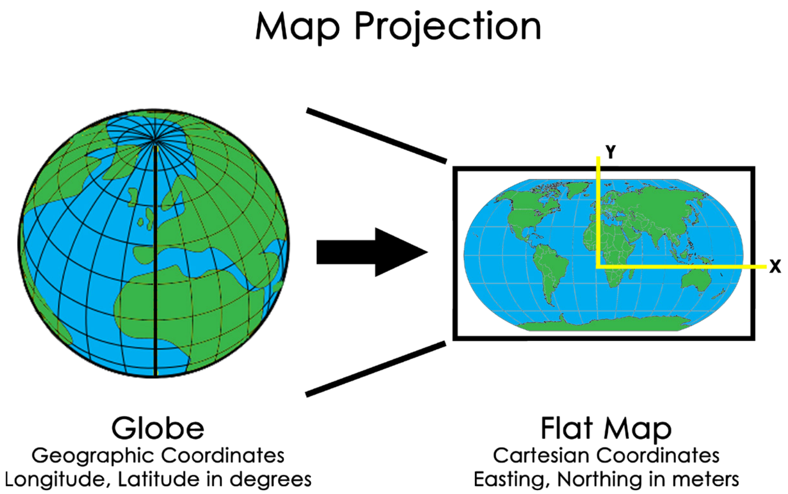



**Figure 18. Map Projection.**
*Source: PAFID, Zingapan, K., 2017)*

- There are many types of "Map projections" to try and preserve some of the following:
  a. Area (e.g. Lambert Azimuthal)
  b. Angles and bearings (e.g. Mercator projection)
  c. Shapes and Sizes (e.g. Robinson)
  d. Distance and Direction (e.g. Sinusoidal)
- To transfer the image of the Earth and its irregularities on to the plane surface of a map, three factors are involved namely:

a. **Geoid** is a rendition of an irregular spheroidal shape. The variations in gravity are accounted for at this level. The observations made on the geoid are then transferred to a regular geometric reference surface.

b. **Ellipsoid or a datum with ellipsoid**. Many countries and organizations have calculated a variety of ellipsoids over the years mainly due to different observations on the geoid from different points upon the Earth.

c. **Projection** is the geographical relationships of the ellipsoid, still in a three-dimensional form, are transformed into two-dimensional plane of a map.

- Majority of projections are based upon cones, cylinders and planes as shown in Figure 19.

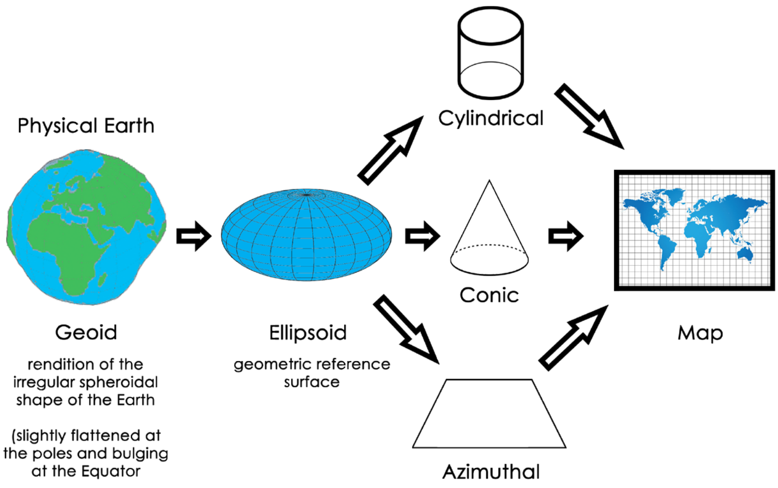



**Figure 19. Cones, cylinders, and planes as bases of the majority of projections.**
*Source: Geoid Ellipsoid - Projection- Relationship (M. Anji Reddy, 2008)*

- Each of these formats have advantages and disadvantages in terms of distortions and accuracy. Every flat map misrepresents the surface of the Earth in some way.
- As a general rule, parts of a map can show one or more, but never all of the following: true shapes, true directions, true distances, and true areas.

### 3. Map Scale

- Map scale is the ratio between the reduced depiction on the map and the geographical features in the real world.
- Map scales are the ratio of the distance between two points on the map and the corresponding distance on the ground.
- The scale may be expressed in three ways and the pictorial representation are:

  a. **Fractional scale**: If two points are 1 km apart in the field, they may be represented on the map as separated by some fraction.

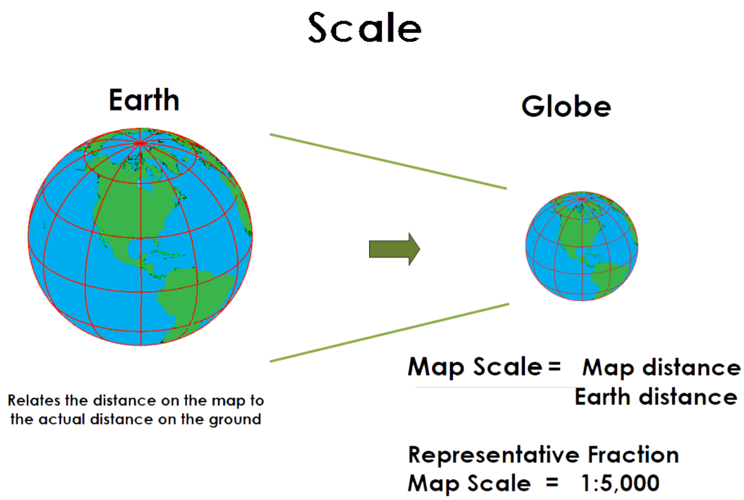



**Figure 20. Map scale.**

*Source: PAFID (Zingapan, K., 2017)*

  b. **Graphic scale**: This scale is a line printed on the map and divided into units that are equivalent to some distance.

  c. **Verbal scale:** This is an expression in common speech such as "four centimeters to a kilometer" and "an inch to a mile". This common method of expressing a scale has the advantage of being easily understood by most map users.

- To calculate scale, use the following formula: map scale = map distance/Earth distance

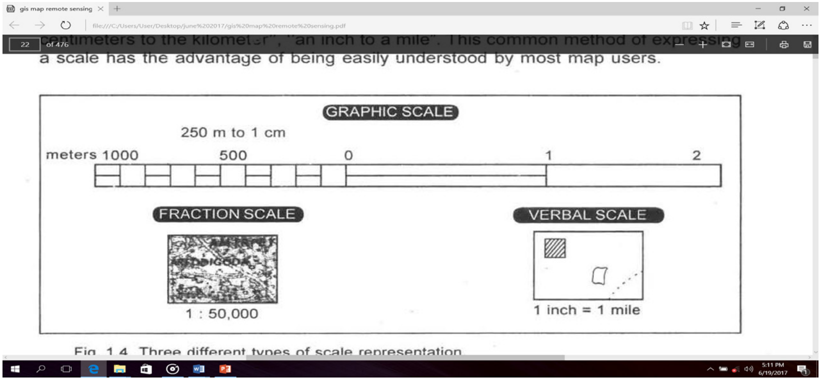



**Figure 21. Graphic scale**

*Source: Three Different Types of Scale (M. Anji Reddy, 2008)*

- Remember to convert everything into the same units. Then convert back to what you were asked.
- Map scale has a huge impact on GIS analysis.
- Maps are broadly classified on the basis of two criteria namely:

  a. **Scale**
  - Small-scale maps cover large areas with little detail e.g. A world map. Scale - 1:250 000
  - Large-scale maps cover small areas with lots of detail e.g. A map of Toronto. Scale - 1:50 000

  b. **Contents and purpose** in terms of thematic contents
  - Physical maps considered as small-scale maps, or cultural map
  - Thematic maps like vegetation maps, transportation maps, land use land cover maps, and remotely sensed imagery

## 4. Design Principles and Rules

**Table 2. Design principles and rules**

| Design Principles | Rules |
|---|---|
| Simplicity | • Harmonious arrangement<br>• Balance presentation, no space is wasted<br>• Observe neatness<br>• Achieving visual hierarchy<br>• Be legible using 1-2 fonts only unless necessary |
| Proximity | • When objects are near one another, they become a visual unit.<br>• Proximity's basic purpose is organization<br>• Good use of proximity produces good white space<br>• Limit number of visual units on page<br>• Don't stick things in corners and middle<br>• Avoid leaving exactly equal amounts of white space between objects unless part of a subset<br>• Allow no confusion about what goes with what<br>• Don't create relationships between things that are not related |
| Alignment | • Alignment helps tie together the elements that make up a page<br>• Avoid mixing text alignments on same page<br>• Always choose centered alignments consciously, never by default<br>• Always find something else on the page to align each new element with |
| Repetition | • Find existing repetitions and strengthen them; avoid overdoing it<br>• Unifies piece<br>• Keeps reader's eye on the page |
| Contrast | • Keep contrast in mind<br>• Creates interesting page. Adds to organization. Must support intended focus, not create new ones.<br>• Avoid using two typefaces that are similar. If they are not exactly the same, they should be different. Don't mix brown text with black titles |

*Source: Dodge, M., Cartographic Principle: Map Design*

### USING AVAILABLE OPEN SOURCE GIS SOFTWARE

In the past, the cost of GIS Software often discourages land rights defenders from digitizing critical spatial information. Today, various open source GIS software are available for free for land rights defenders allowing them to develop GIS databases of the maps of their community partners. One of the more popular open source GIS software is Quantum GIS (QGIS).

**What is QGIS?**

Quantum GIS (QGIS) is a user friendly Open Source Geographic Information System (GIS) that runs on Linux, Unix, Mac OSX, and Windows. QGIS supports vector, raster, and database formats. It lets the user to browse and create map data on their computer. It supports many common spatial data formats (e.g. ESRI shapefile, geotiff). QGIS supports plug-ins to do things like display tracks from the GPS units. QGIS is a free downloadable Open Source software.

QGIS is an operating system designed to capture, store, manage, manipulate, visualize, model, analyze, and display spatial data. It is an enabling tool that support GIS as an integrating technology that provides a platform for studying spatial relationships. It makes connections between activities based on geographic proximity that had often been unrecognized. Lastly, it offers new insights and explanations that are vital to understanding and managing resources (Goodchild and Kemp, 1990; Cowen, 1990).

Database management and data processing of spatial information can now be easily processed using QGIS.

*Data Base Management* refers to unique issues in the maintenance of spatial data such as technical error or level of accuracy, input, and storing data; retrieving data; and metadata. Data management is one of the key issues in determining the usability of spatial data. The application of QGIS software has been used by PAFID for many years.

Another important operation is *Data Processing* which is the restructuring of data to increase their usefulness and add values for particular purpose. It involves calculation, analysis, comparison, data manipulation, sorting, searching, and transformation of data. Some of its important functions are summarizing, computing averages, graphing, creating charts and visualizing data. When answering questions that may not be explicitly stated in the data, this is called data analysis.

**Relevance of QGIS**

QGIS is used for solving complex planning and management problems because it has the ability to investigate in terms of: (a) ***Locations*** – "where", overlaps; (b) **Quantities** – "what", lengths and areas, most and least; (c) **Distances** – scoping, proximity; (d) ***Distributions or densities*** – clustering, hotspots; (e) ***Discern Patterns*** – correlation, causality, random; (f) **Trends** – monitoring change or behavior through time, movement; and (g) ***Models*** – "what if", scenarios, decision support systems. Hence, the QGIS can be applied in different fields, to wit:

- Medicine – origin case of GIS analysis
- Navigation – airplanes, cars, shipping
- Hazards – risk, vulnerability
- Networks – streets, electricity, transport
- Land-use planning and land management
- Conservation
- Natural resources management – one of the first applications and driver of the development of modern GIS

Many governments in different countries across the globe are maintaining huge geographic database for analysis and make such information open to public use.

QGIS can process geographic data from a variety of sources and integrate it into a map project which is interactive. On the computer screen, map users can data capture from the field using GPS Garmin receiver that provide spatial location. It can scan a map in any direction, zoom in or out, and change the nature of the information contained in the map. It organizes geographic data so that the user reading a map can select necessary data for a specific project or task. A thematic map has a table of contents that allows the reader to add layers of information to a base map of real-world locations.

An important skill that land defenders should possess is the ability to validate the veracity of the tenurial instruments issued to them.

Conflicts arise among various claimants regarding the actual location of the awarded lands. Often, the lack of spatial information exacerbates conflicts among stakeholders on ground. Hence, it is important that basic sectors have the ability to verify the information indicated in the formal instruments, for instance, the Certificate of Land Ownership Award (CLOA)[1], they have received from the government.

One way of validation is by plotting the lot description of a CLOA Transfer Certificate Title (TCT)[2] in a map using GIS.

## Plotting CLOA

The following exercise was based on the actual CLOA. However, for security reasons, some elements of the map were replaced with fictitious names.

**EXERCISE: CLOA TCT**

Objective: To plot a CLOA TCT lot description

**Research**

1. Study the CLOA TCT document
2. Find the general area where the CLOA is located:
    - Province
    - Municipality
3. Find the name of the "Tie Point"
    - The "Tie Point" is a named *muhon* or geodetic monument used to locate the CLOA TCT boundary corner marked "1" or Corner "1". Tie Points are often Bureau of Land Location Monuments (BLLM), Barrio Boundary Monuments (BBM), Municipal Boundary Monuments (MBM), PRS92 monuments, and others. These monuments are often named with Cadastre Numbers.

[1] A CLOA is a tenurial instrument issued by the Department of Agrarian Reform (DAR) to landless farmers.

[2] TCT is a document issued by the Registry of Deeds (ROD) that will process the generation of CLOA. It contains the geophysical location, measurement, registration number, and name of the owner of the land to whom its ownership was transferred to from the Republic of the Philippines.

4. Find the technical description of the "Tie Line" that connects Corner "1" of the CLOA to the "Tie Point" or named *muhon*:
   - Bearing in degrees, for example, N25°25'W
   - Distance in meters
5. Find the technical description of the CLOA boundary lines connecting the CLOA boundary corners:
   - Bearing in degrees
   - Distance in meters

**PPCS-TM Zone or Projection Number**

Refer to Annex 7 of DENR Memorandum Circular 2010-16 Manual on Land Surveys.

- Note the province where the CLOA TCT is located
- Check the PPCS-TM Zone for the CLOA TCT technical description

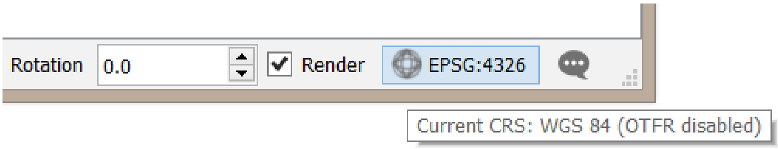
**PRS92 Certification of Tie Point Coordinates**

Go to the DENR Regional Office Land Management Service and request a PRS92 Certification for the CLOA TCT "Tie Point". The Certification must show the following (sample attached):

- The name of the "Tie Point"
- The PRS92 coordinates of the "Tie Point" expressed as longitude and latitude in degrees, minutes, and seconds; and ellipsoidal height or height above the PRS92 ellipsoid (HAE) in meters
- The PRS92 coordinates of the "Tie Point" expressed as eastings and northings in meters; and geoidal height or mean sea level (MSL) in meters
- Certificate data and place; and name and signature of certifying officer

**QGIS Settings**

1. Open Quantum GIS. In the lower right corner, click on the Coordinate Reference System (CRS) icon

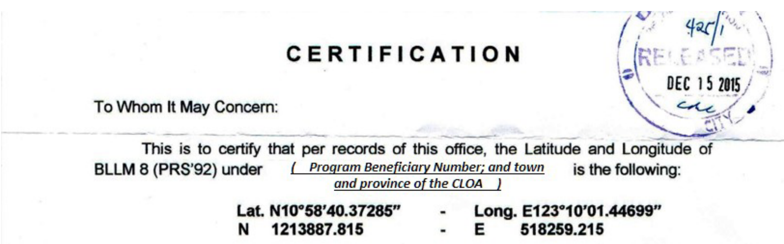



2. Set the following:
   - Check the box next to 'Enable on the fly' CRS transformation
   - Next to 'Filter', type PRS92
   - From the research, select the correct PPCS-TM Zone for the CLOA TCT, for example, PRS92 / Philippines zone 4 (EPSG: 4324)
   - Click OK

3. In the main menu, click on Settings > Options and select the Digitizing tab
4. Set the following:
   *Feature creation*
   - Uncheck the box next to 'Suppress attributes pop-up windows after each created feature'
   *Rubberband*
   - Line width = 1
   *Snapping*
   - Default snap mode: To vertex
   - Default snapping tolerance: 50 pixels
   - Search radius for vertex edits: 10 pixels
   *Vertex markers*
   - Check the box next to 'Show markers only for selected features'
5. In the main menu, click on Settings > Snapping Options
   - Set the Snapping mode to All layers
   - Check the box next to 'Enable topological editing'
   - Click OK
6. Ensure that the following Plugins are installed:
   - Azimuth and Distance version 0.9.3
   - QuickMapServices
7. Save your QGIS file by clicking on Project> Save in the main menu

**Prepare the traverse import text file**

1. Refer to the PRS92 Certification of Tie Point Coordinates
   - It is important for land rights defenders to possess the CLOA TCT as it provides the coordinates of the location of the awarded land. It must also be ensured that the document is validated by the government seal (see Annex A for a sample Certification of Tie Point Coordinates).
   - Note the coordinates for the Tie Point of the CLOA TCT (see Figure 24):


CERTIFICATION

RELEASED DEC 15 2015

To Whom It May Concern:

This is to certify that per records of this office, the Latitude and Longitude of BLLM 8 (PRS'92) under ( Program Beneficiary Number; and town and province of the CLOA ) is the following:

Lat. N10°58'40.37285" - Long. E123°10'01.44699"
N 1213887.815 - E 518259.215

**Figure 24. Portion of the PRS92 Certification of Tie Point Coordinates showing the coordinates of the CLOA TCT.**

2. Following is a sample lot technical description of a CLOA TCT :

## TECHNICAL DESCRIPTION

Tie Line From BLLM No. 8, (___*Cadastre Number; and the town and province of the CLOA*__)

to Corner "1" of TCT No. (___*Transfer of Certificate Title Number*___)

| | | |
|---|---|---|
| **0 - 1** | **N25°25'W** | **1305.31** |

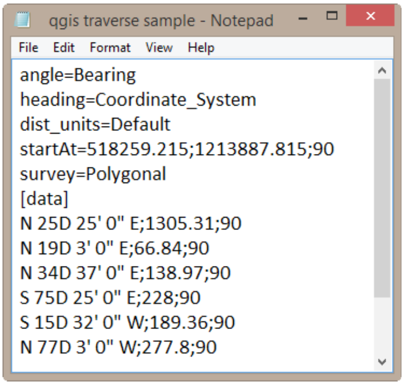
| LINES | BEARINGS | DISTANCES |
|---|---|---|
| 1 - 2 | N19°03'E | 66.84 |
| 2 - 3 | N34°37'E | 138.97 |
| 3 - 4 | S75°25'E | 228.00 |
| 4 - 5 | S15°32'W | 189.36 |
| 5 - 1 | N77°03'W | 277.80 |

**Figure 25. Sample lot technical description of a CLOA TCT.**

- Type the technical description of the “Tie Line” and CLOA boundary lines in an Excel file using the following columns:

| Tie Line and Boundary Lines | North Or South | Bearing Degrees, ° | Bearing Minutes, ‘ | Bearing Seconds, “ | East Or West | Distance, meters |
|---|---|---|---|---|---|---|
| “Tie Line” : “Tie Point” to Corner “1” 0-1 | N | 25 | 25 | 0 | E | 1305.31 |
| 1-2 | N | 19 | 3 | 0 | E | 66.84 |
| 2-3 | N | 34 | 37 | 0 | E | 138.97 |
| 3-4 | S | 75 | 25 | 0 | E | 228 |
| 4-5 | S | 15 | 32 | 0 | W | 189.36 |
| 5-1 | N | 77 | 3 | 0 | W | 277.8 |

3. Below is a sample of the traverse format used by the QGIS Azimuth Distance Calculator Plugin:


qgis traverse sample - Notepad
File Edit Format View Help
angle=Bearing
heading=Coordinate_System
dist_units=Default
startAt=518259.215;1213887.815;90
survey=Polygonal
[data]
N 25D 25' 0" E;1305.31;90
N 19D 3' 0" E;66.84;90
N 34D 37' 0" E;138.97;90
S 75D 25' 0" E;228;90
S 15D 32' 0" W;189.36;90
N 77D 3' 0" W;277.8;90

angle=Bearing
heading=Coordinate_System
dist_units=Default
startAt=518259.215;1213887.815;90
survey=Polygonal
[data]
N 25D 25' 0" E;1305.31;90
N 19D 3' 0" E;66.84;90
N 34D 37' 0" E;138.97;90
S 75D 25' 0" E;228;90
S 15D 32' 0" W;189.36;90
N 77D 3' 0" W;277.8;90

**Figure 26. Sample traverse format used by the QGIZ Azimuth Distance Calculator Plugin.**

4. Use a text editor like Notepad to reformat the technical description for the Azimuth Distance Calculator Plugin. Copy the coordinates of the “Tie Point” (Corner 0) in the line after ‘startAt=’

   startAt=TiePoint-X-Easting; TiePoint-Y-Northing;90
   for example,
   startAt=518259.215; 1213887.815;90

5. The lot descriptions are also reformatted and inserted under [data] as below:
   [data]
   NorthOrSouth Bearing-DegreesD Bearing-Minutes’ Bearing-Second” EastOrWest;Distance;90

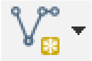
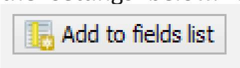
   for example,
   [data]
   N 25D 25’ 0” E;1305.31;90

   In the Excel file for the technical description of the Tie Line and Boundary Lines, the CONCATENATE function can be used to reformat the technical description, as below:
   =CONCATENATE(NorthOrSouth,” “, Bearing-Degrees,”D “,Bearing-Minutes,”’ “,Bearing-Seconds,””” “,EastOrWest,”;”,Distance,”;90”)

6. Alternatively, use the Excel file ‘QGIS traverse calculator template’ to reformat the entries for:
   - startAt
   - [data]

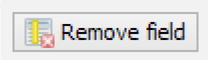
7. Copy-paste the entries into the Notepad file 'QGIS traverse blank form' and 'Save-As' the TCT traverse data to a new text file before closing Notepad. Ensure that no blank spaces follow the entries.

**Create an empty polygon shapefile**

1. In QGIS, click on the New Shapefile Layer  and use the following settings:
   - Type : Polygon
   - Check that the Selected CRS is the PRS92 PPCS-TM Zone of the CLOA TCT for example, EPSG:3124, PRS92 / Philippines zone 4
   - Below New field, add 8 new fields one after another using the settings below. Click on the 'Add to fields list' button 

 to add each New field :

| Name | Type | Length | Precision |
|---|---|---|---|
| Name | Text data | 200 | |
| SurveyPlan | Text data | 50 | |
| LotNumber | Text data | 100 | |
| ClaimNo | Text data | 100 | |
| TCTNo | Text data | 100 | |
| TiePoint-Name | Text data | 100 | |
| AreaSQM | Decimal number | 20 | 15 |

For mistakes, use the Remove field button 


   - When done, click OK
   - Next to File name, type a file name
   - Next to Save as type, ensure that ESRI Shapefile is selected
   - Click OK

2. In the Layers panel, select the new empty polygon shapefile and click on the Toggle Editing button 

3. Click on Plugins> Topography> Azimuth and distance

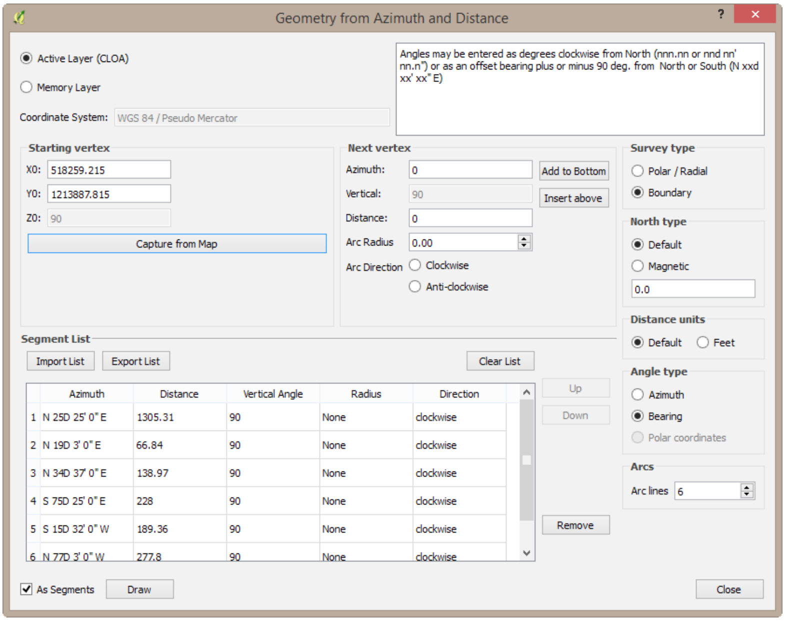
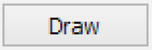



**Figure 27. Command box showing the Azimuth and Distance.**

4. In the Azimuth and distance plugin, click on the Import List button


- Select the Notepad file of the reformatted CLOA lot technical description and click Open
- Check on the box next to 'As Segments'
- Below 'Survey type', check that 'Boundary' is selected
- Next to Arc Direction, select 'Clockwise'
- Below 'North type', select 'Default'
- Below 'Distance units', select 'Default'
- Below Angle type', select 'Bearing'
- Click on the Draw button 

- Fill up the data for the TCT in the pop-up form and click OK
- Close the Azimuth and Distance plugin

5. Click on Settings> Snapping Options and use the following settings:
   - Layer selection : Advanced
   - Ensure the box next to the CLOA polygon layer is checked
   - Set the snap mode to vertex
   - Check that tolerance is set to 50 pixels
   - Check that 'Enable topological editing' is enabled
   - Check that 'Enable snapping on intersection' is enabled
   - Click Ok

6. On the Attributes toolbar, click on the 'Select Features' button  and select the CLOA lot
7. On the Digitizing toolbar, click on the Node tool 
   - Click the Node tool on the CLOA polygon until the Vertex editor pane is displayed. Use the Node tool or the Vertex Editor pane to select the nodes or vertices of the CLOA polygon.
   - In the Vertex Editor pane, note the coordinates for the "Tie Point" or Corner 0 and the CLOA Corner "1" which are entered in row 0 and row 1, respectively
   - In the Vertex Editor pane, select Corner 0 and press 'Delete' on the keyboard to delete the Tie Point
   - Check that the coordinates for the CLOA TCT Corner "1" are now displayed in row 0 of the Vertex Editor pane
   - In the Map Navigation toolbar, click on the 'Pan' and 'Zoom In' buttons to zoom in on TCT Corner "1" which should now be displayed as row 0 in the Vertex Editor pane.
   - On the Digitizing toolbar, click on the Node tool  and click on the CLOA polygon until the Vertex Editor pane is again displayed
   - In the Vertex Editor pane, check that the coordinates in the last row are identical to the coordinates of CLOA Corner "1"
   - In the Vertex Editor pane, select the second-to-the-last row and press 'Delete' on the keyboard to delete the point (see Figure 28):

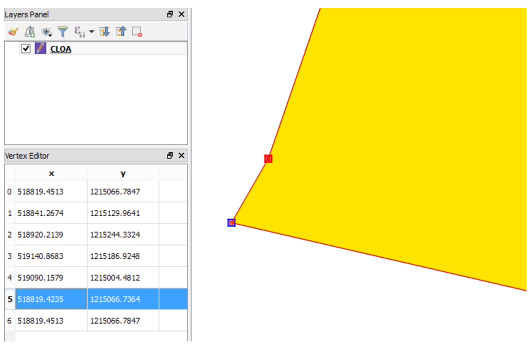



**Figure 28. QGIS workspace showing the Vertex Editor pane.**

   - Once finished, click on the Save edits button  to save your edits

**Calculate the area of the CLOA TCT**

1. Right-click on the polygon layer and select 'Open Attribute Table'
   - Click on the Field Calculator button 
   - Check 'Update existing field' and in the box below, select

AreaSQM

- Under the Search box, click Geometry and double-click on area
- Click OK
- Click on the Save edits button  to save your edits, then click on Toggle Editing button  to close the editing session

2. Click on Web> QuickMapServices>Google and select Google Satellite

3. Use the Print Composer to create a CLOA map and save your QGIS document before closing QGIS.

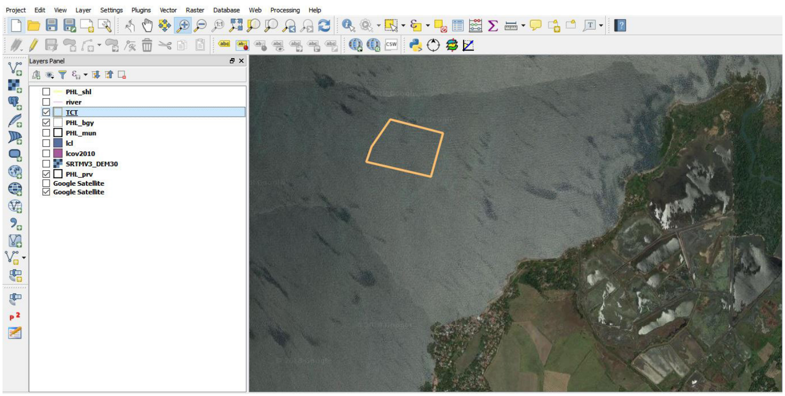



**Figure 29. Overlaying the plotted polygon in the Google Sattelite Imagery.**

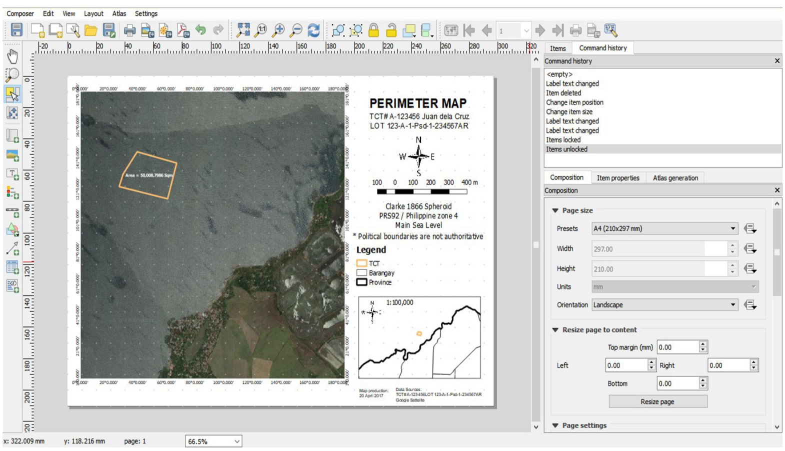



**Figure 30. Creating the CLOA map in the 'Print Composer'.**

**Data Output –** refers to the method used to visually display analysis performed using GIS. Output can take many forms such as text, sound, tables of data, graphs, commands, etc. Depending on the form of output required, the data can be transmitted by a range of devices for presentation.

Digital Map Production is a graphic representation or scale model of spatial concepts. It is a means for conveying geographic information. Figure 31 shows a sample Perimeter Map produced by Ms. Naungayan during a four-day GIS Training last April 16-19, 2017 held at Brentwood Suite in Quezon City. The GIS Training was jointly organized by PAFID and ANGOC.

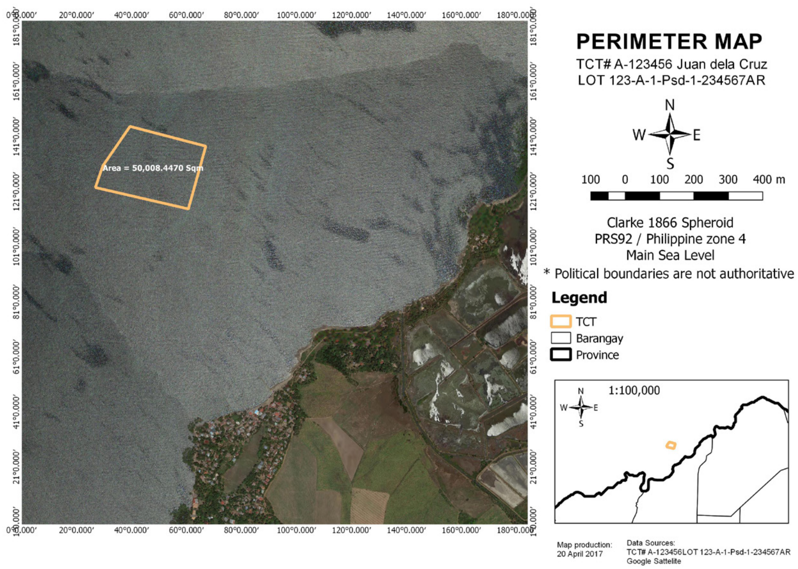



**Figure 31. Sample Perimeter Map.**

It is important that the output map be shown and validated with the farmer owners, and check whether the actual location of the CLOA is consistent with the coordinates indicated in the TCT.

In the example above, the CLOA is erroneously located in the ocean instead on land, showing an erroneous survey.

Rhind (1977) enumerated several good reasons for computer map production, to wit:

- To make existing maps more at a quicker pace.
- To make existing maps at a cheaper rate.
- To make maps for specific user needs.
- To make map production possible in situations where skilled staff are unavailable.
- To allow experimentation with different graphical representations of the same data.
- To facilitate map making and updating when the data are already in digital form.
- To facilitate analysis of data that demand interaction between statistical analysis and mapping.
- To minimize the use of the printed map as a data store and thereby to minimize the effects of classification and generalization on the quality of the data.
- To create maps like the 3-D type.
- To create maps in which selection and generalization procedures are explicitly defined and consistently executed.
- Introduction of automation can lead to a review of the whole map-making process, which can also lead to savings and improvements.

***Source: (M. Anji Reddy, 2008)***

Moreover, converting the analog map to digital form is either by manual digitization or by scanning. Manual digitization is the commonly used technique for including analog data in a digital database.

## A case of local map production by the Subanen community in Bayog, Zamboanga del Norte, Philippines

### Introduction

Just like most Indigenous communities in Mindanao, the Subanen community in the Municipality of Bayog, Zamboanga Del Norte faces numerous challenges that threaten the integrity of their environment. Illegal gold mining activities in the town of Bayog have been going on for the past 45 years and small-scale miners have illegally claimed hundreds of hectares of lands, leading to tremendous environment pollution. The illegal miners used cyanide, nitric acid, and other hazardous chemicals including mercury to process the gold ore. Tons of cyanide and mercury-laden mine wastes flow out freely from shallow ponds dug by the illegal miners damaging hundreds of hectares of fertile farmlands. What was even worse was the fact that the unabated illegal mining activities resulted into over 100 tunnels, which crisscrossed beneath the surface of the gold-rich mountains in the Subanen Ancestral Domain.


Figure 22. Map showing the Municipality of Bayog, Zamboanga Del Norte, Philippines.

In 2006, in order to safeguard what remains of their traditional lands, the tribe submitted the application for a Certificate of Ancestral Domain Claim (CADC) covering land located in this town to the National Commission on Indigenous People's (NCIP). The application covered 22 barangays in Bayog: Dimalinao, Boboan, Depore, Pulangbato, Dipili, Kahayagan, Liba, Conacon, Bantal, Boboan, Deporehan, Sigacad, Balukbuhan, Matin-ao, Datagan, Camp Blessing, Kanipaan, Bonbonan, Depase, Matun-og, Baking and Canoayan. The Subanen knew that the road ahead would not be easy and they will have to respond to the challenges posed by those who had vested interests over their lands.

To strengthen their advocacy for the recognition of their rights over their ancestral domains, the Subanen elders needed to produce evidence. The Subanen also needed to inform the public of the dangers posed by the illegal mining activities of the various ecosystems in the municipality.

**Mapping their Territory**

With assistance from PAFID, the community constructed a Participatory 3D-Model. Through the P3DM, community members were able to generate spatial information on the extents of their traditional territory, their traditional management zones and land-uses of the Subanen domain. Furthermore, they were able to analyze and show the impacts of the illegal mining activities in their ancestral lands.

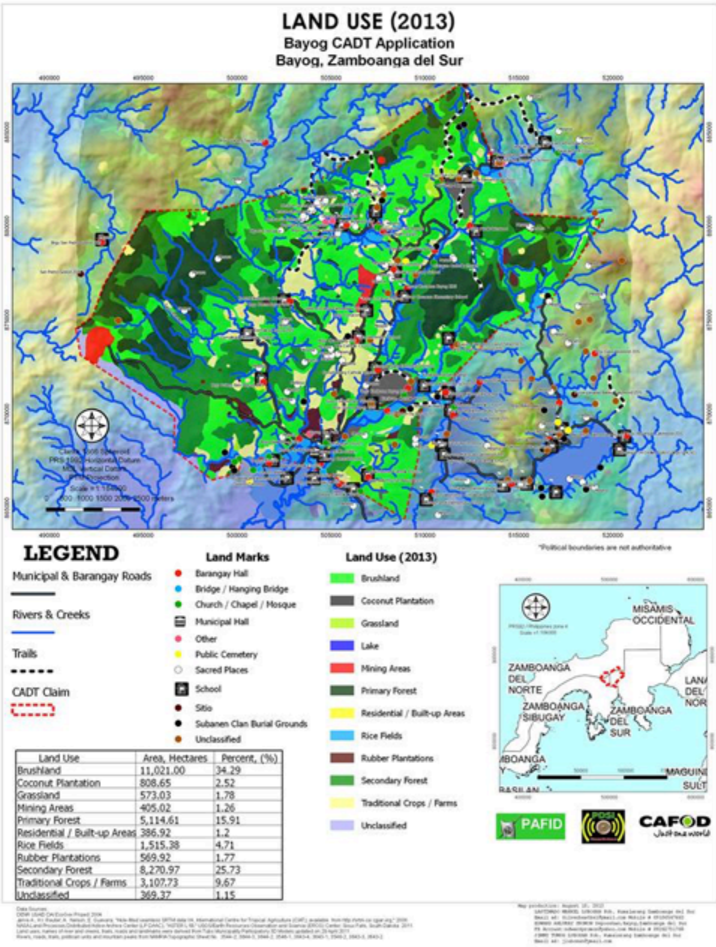
While the P3DM provided an excellent venue for the Subanen community to generate, analyze and present the state of their territory, the spatial information produced by the P3DM needed to be digitized and to be further analyzed in order for the Subanen to produce data and maps critical to their advocacy. Hence, it was decided that a training on the use of Quantum GIS an Open Source GIS Software would be conducted. Participants representing the villages in the domain claim would be nominated by the community. Initially, the trainees doubted their ability to cope with the demands of the training. They cited their limited educational status and their unfamiliarity with computers and GIS software. Furthermore, they shared the notion that mapping is the exclusive domain of professional engineers and that ordinary folks have no business trying it.

The community nominated five Subanen participants; two NGO participants along with two NCIP trainees joined them. All participants had varying levels of familiarity with information technology as well as educational attainment. The training took a total of 12 days which were broken down into three separate sessions to enable the participants to examine and validate their work with the community using the P3DM. Participants learned how to transfer the information from the P3DM to a digital image and the use of the on-screen digitizing utility of Quantum GIS. Furthermore, they were trained on the basics of map production including Geographic projection and Map layout.

**Results**

After nearly a month, the Subanen participants were able to produce a complete map layout of their Ancestral Domain. The map had spatial information and thematic layers including hydrology, road networks, management zones, risk areas, the perimeter of the ancestral domain claim, the proposed no-go zones, land-use and land cover. In a General Assembly, the map was later presented to the community members for final editing and validation. With minimal edits and comments, the map was resoundingly approved and endorsed by the community and formally adopted as the accurate and proper representation of their ancestral domains. Copies of the map were formally submitted to the Office of the Mayor, the DENR and other concerned agencies.

In 2015, the Subanen community was invited to participate and present their experience in PGIS in the Regional Conference of the Catholic Aid for Overseas Development (CAFOD). Copies of their map were prominently displayed in the conference.




| Land Use | Area, Hectares | Percent, (%) |
|---|---|---|
| Brushland | 11,021.00 | 34.29 |
| Coconut Plantation | 808.65 | 2.52 |
| Grassland | 573.03 | 1.78 |
| Mining Areas | 405.02 | 1.26 |
| Primary Forest | 5,114.61 | 15.91 |
| Residential / Built-up Areas | 386.92 | 1.2 |
| Rice Fields | 1,515.38 | 4.71 |
| Rubber Plantations | 569.92 | 1.77 |
| Secondary Forest | 8,270.97 | 25.73 |
| Traditional Crops / Farms | 3,107.73 | 9.67 |
| Unclassified | 369.37 | 1.15 |

**Figure 23. Land Use Map of the Bayog CADT area.**

## Lessons learned

The Bayog experience clearly showed that ordinary folks can learn basic GIS and will be able to create a simple spatial database and generate maps. Critical factors include that the training is properly designed and the trainers have the proper patience, understanding of the situation and fortitude to conduct the capacity building activity.

The spread of social media such as Facebook into the rural areas has proven to be very effective breaking barriers and enabled ordinary people to remove their fears of digital technology. This is especially true with the younger generation who are very eager to learn and expand their knowledge in the field of ICT.

The use of the P3DM, along with the upscaling into Quantum GIS, is very sound illustration on the convergence of various PGIS tools and methodologies that can empower the people and increase their capacity to advocate and engage the more powerful sectors of society.

The whole PGIS exercise has enabled the Subanen to learn new technologies to strengthen their advocacy and has shown the greater public that they are able to adapt new technologies and learn skills that are more complicated. This has resulted into a very noticeable increase in local pride that is clearly shown in their engagements with the government and other sectors of society. They now proudly declare that they are mappers and that they have GIS practitioners in their ranks. ■