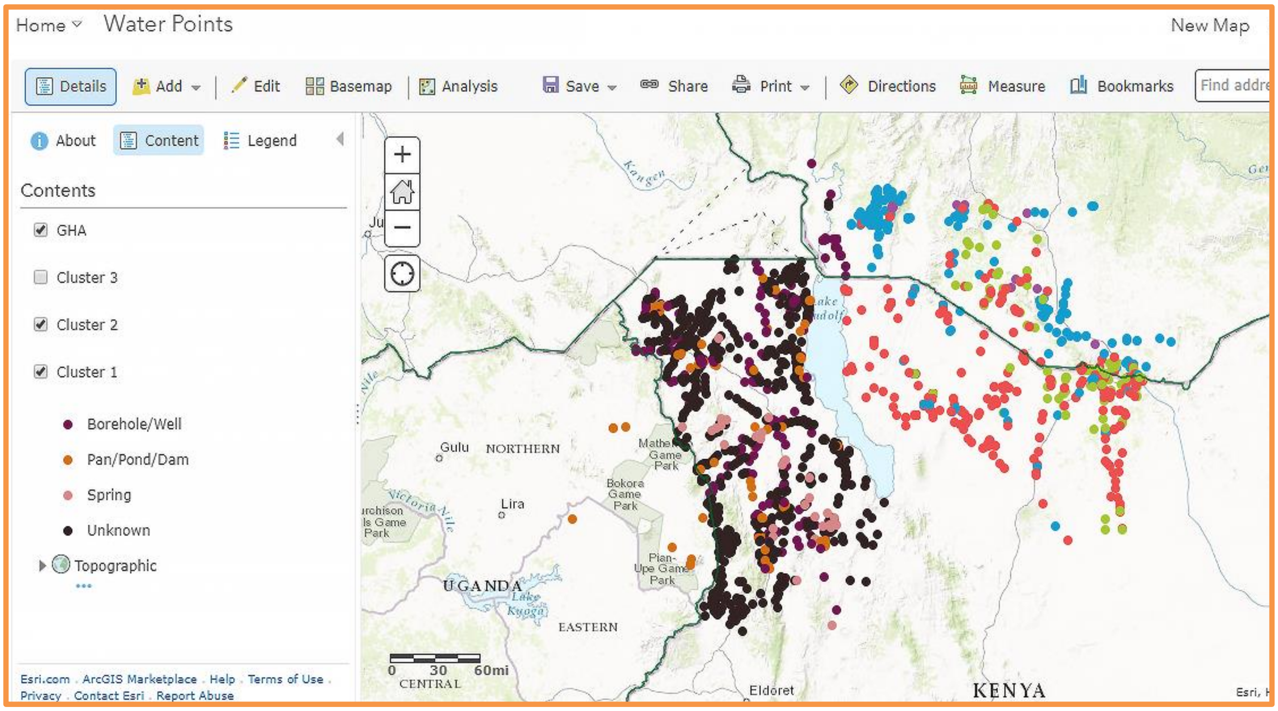
TRAINING MODULE

Basic GIS and Web Mapping Training

(Using Quantum GIS and ArcGIS Online)



ICPAC
IGAD Climate Prediction & Applications Centre

Organized by Regional Pastoral Livelihoods Resilience Project in collaboration with IGAD Climate Prediction and Applications Centre (ICPAC)

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MODULE -1: INTRODUCTION

1.1. Introduction to Geospatial Technology and GIS

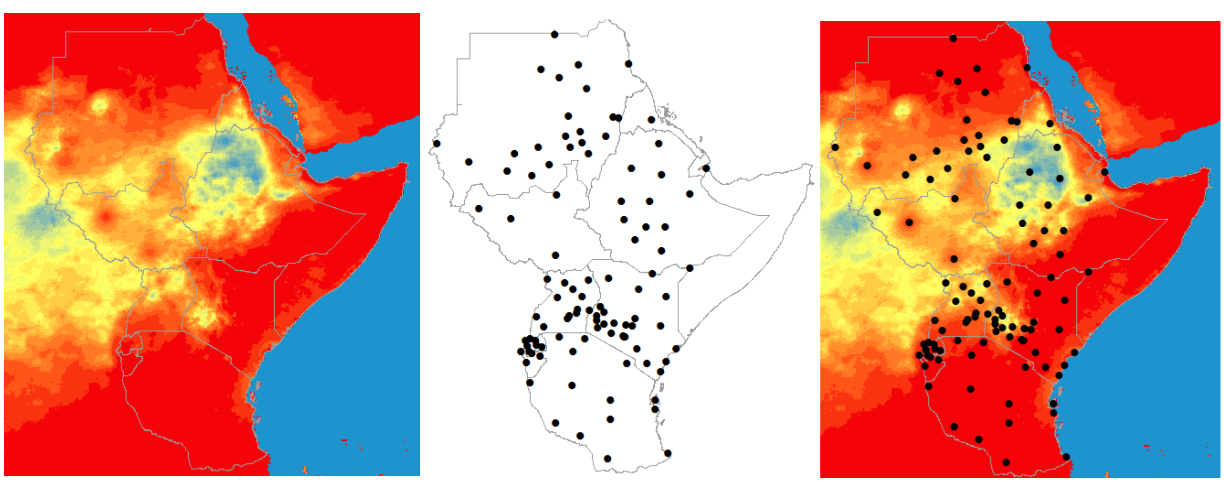
1.1.1. Introduction to Geospatial Technology (refer the PowerPoint presentation)

1.1.2. Introduction to GIS (refer the PowerPoint presentation)

1.2. Overview of Spatial Data

1.2.1. Source and Nature of Spatial Data

The sources for spatial data can be from different sources including Field observation/measurement, GPS based data collection, Remote sensing and software based derivations like map digitization. Now days Satellite based data acquisition is providing continues image products for almost all areas of the world at different spatial resolutions. The field based data collection also remain important in providing ground based accurate measurements which often helps to calibrate space based products. For climate data these two sources plays a crucial role and the limitation of one is also substantiated by the other. For instance, issues related to accuracy on the satellite products can be verified by the ground station readings while the discrete nature of data obtained from ground observations can be reasonably interpolated with the help of satellite data products which provides a continuous raster data for an area.



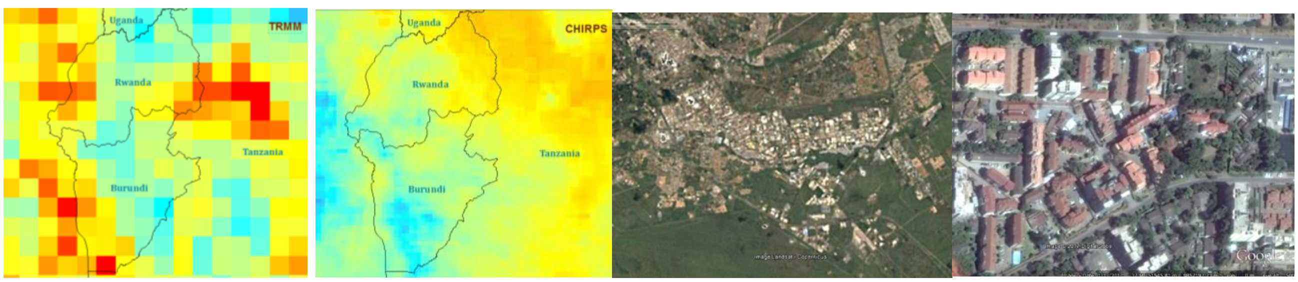
1.2.2. Spatial and temporal resolutions

Image resolution is a factor of precision/fineness of pixels to represent certain portion of the earth surface. There are two categories of image resolution that are very important to understand in spatial data and these are spatial and temporal resolution. The spatial resolution categorically refers to the size of a pixel used to represent certain area of the surface. The bigger the pixel size, the low the image resolution. For example, Image with 5km x 5km resolution means 25 square kilometer of area is represented by one pixel. Compared to 50km x 50km it can be said that the previous image has higher resolution. On the other hand, temporal resolution refers to the repetitiveness of the data capture like hourly, daily, decadal, monthly, annual etc.

Understanding the spatial and temporal resolution is quite essential before defining a methodology in any of the natural systems modeling including climate. Some image resolutions are appropriate only for large areas and for small areas high resolution products are recommended.

Some climate data from different sources are summarized for your further exploration

Satellite/Product Name	Spatial Resolution	Temporal resolution	Remark
CHIRPS 2.0	~5km x 5km	Decadal	Blend
TAMSAT	~4km x 4km	Daily	Sat.
TRMM	~25kmx25km	3hrs	Sat.
GPM	~10km x10km	“	Sat.
WorldClim	~1km x1km		Station interpolation
Landsat	30m x 30m /15m		Multi-spec Image
Sentinel 2	10 x 10m		Multi-spec image



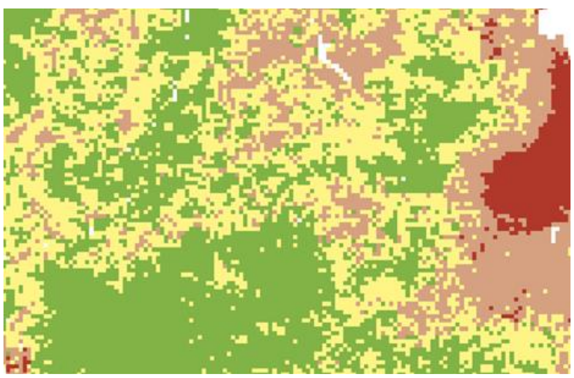
50km 1km 30m 0.6m

For the greater horn region all the above products are available in common raster file formats. Some of the limitations in using these products are technical and professional capacity to manipulate data and make a meaning to explain some of the natural and human induced phenomena around us.

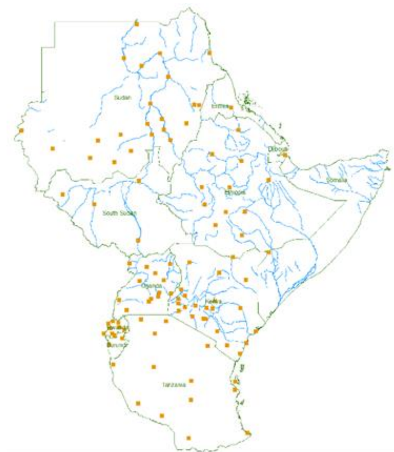
1.3. GIS Data Models and Coordinate Geometry

1.3.1. GIS Data Models

The nature of the spatial data can be of vector or raster format. Vector data formats are used to represent discrete type of data and often represented by point, line and/or polygon. Raster data types are used to represent continuous data types like rainfall, temperature, topography...etc. The smallest entity of a vector is a point whereas for raster it is a pixel. The type of data modeling depends on the nature of the data, scale of the map, and our preference for the analysis that follows. However, it is good to remember that conversion of raster to vector or vise-versa is always possible although it might compromise the quality/form of the original data. For example, if you convert a raster to vector the edge may be generalized and may not follow the exact boundaries. It is highly recommended to avoid back and forth conversion of your data between vector and raster unless you are required to do so. It is also worth to remind you the many raster file formats which sometimes creates obstacles to data processing as all data formats are not compatible to the softwares we may choose to use.



Raster Data Model



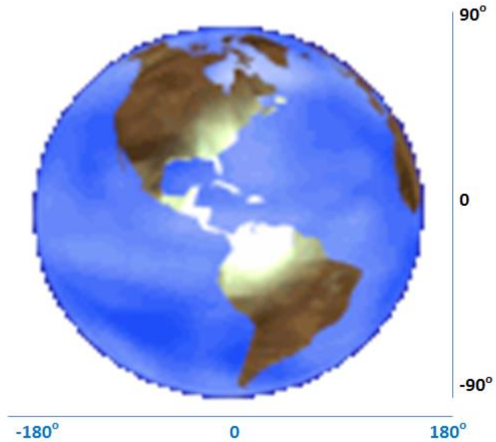
Vector Data Model

1.3.2. Coordinate systems

Any data that represent the location/position is called spatial data. The most common ways of representing spatial data is through the use of X and Y or longitude and latitudes which are obtained through the system called coordinate system. There are two categories of coordinate systems and these are Geographic coordinate systems (uses degrees minutes and seconds) and projected coordinate systems (uses meter as a unit of measurement often with six/seven digit numbers).

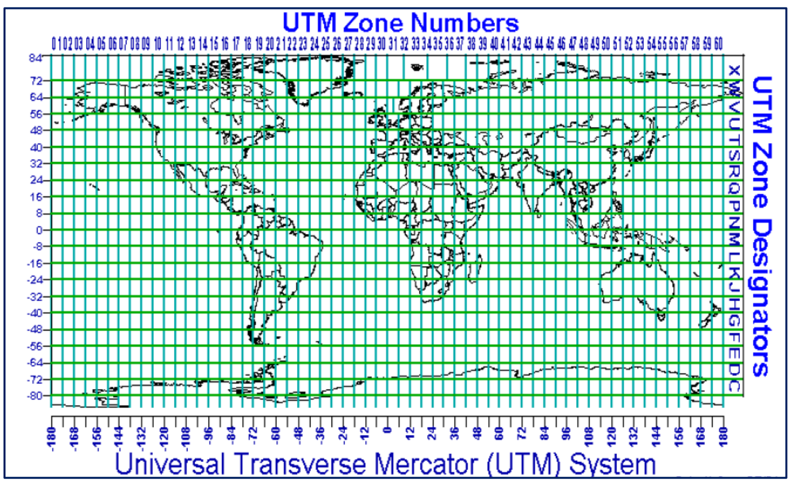
(a) Geographic Coordinate Systems

It uses Latitudes (0-90oN-S) and Longitudes(0-180oE-W) and the Latitudes are measuring the distance from the equator(Y-dimension) and Longitudes are measuring distance from Greenwich (X-dimension) either be positive on the north hemisphere or negative on the south side of the equator are measured using degrees, minutes and seconds (° , ‘ , ’’).



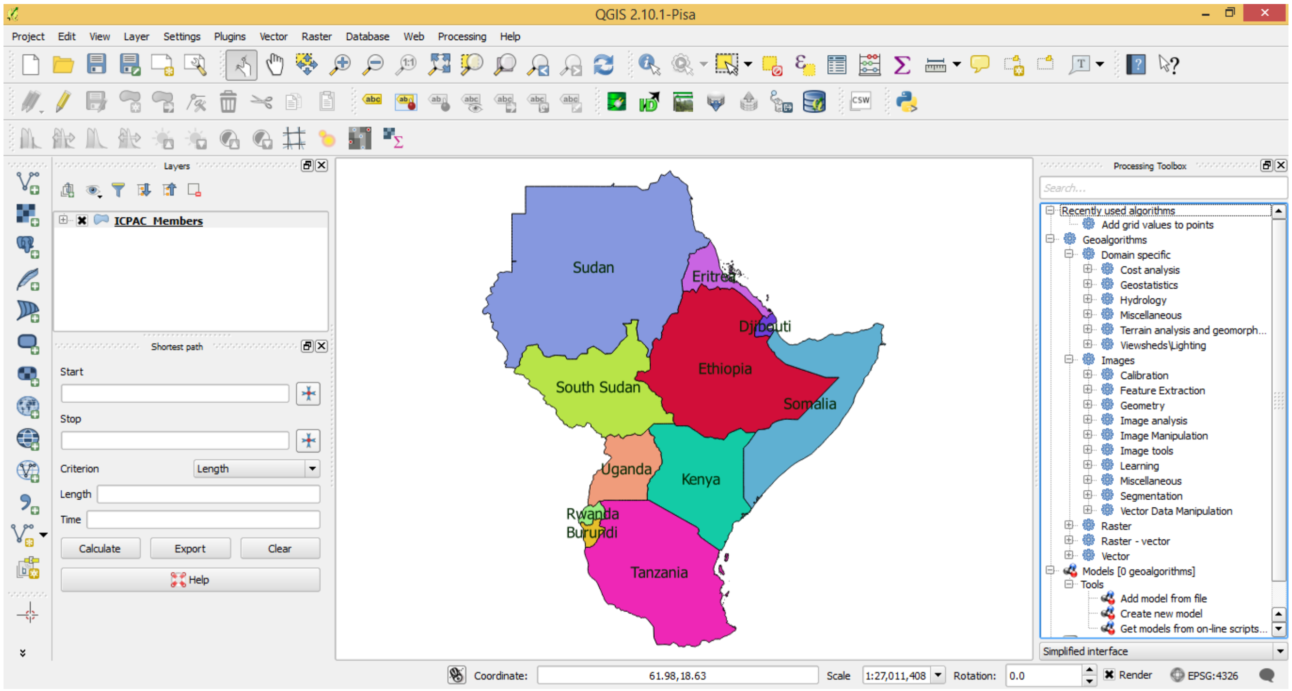
(b) Projected Coordinate Systems

This system by Mercator divides the globe in to 60 grids called zones and uses meter as a unit of measurement.



1.4. Overview of Quantum GIS Software

Quantum GIS often called QGIS is the leading open source GIS software and have quite many functionalities. In addition to the various toolboxes that one can use for manipulating spatial data, the software is also a launching pad for many other open source GIS software like GRASS, SAGA, Python, R, TauDEM, and GDAL. The software is simple and provides a state of the art facilities as the best open source GIS software available to the user community.



Many of the tools and procedures are straightforward and all the tutorial documents on the tools and functions are available at http://www.qgistutorials.com/en/.

MODULE -2: CREATE, EDIT AND MODIFY SPATIAL AND ATTRIBUTE DATA

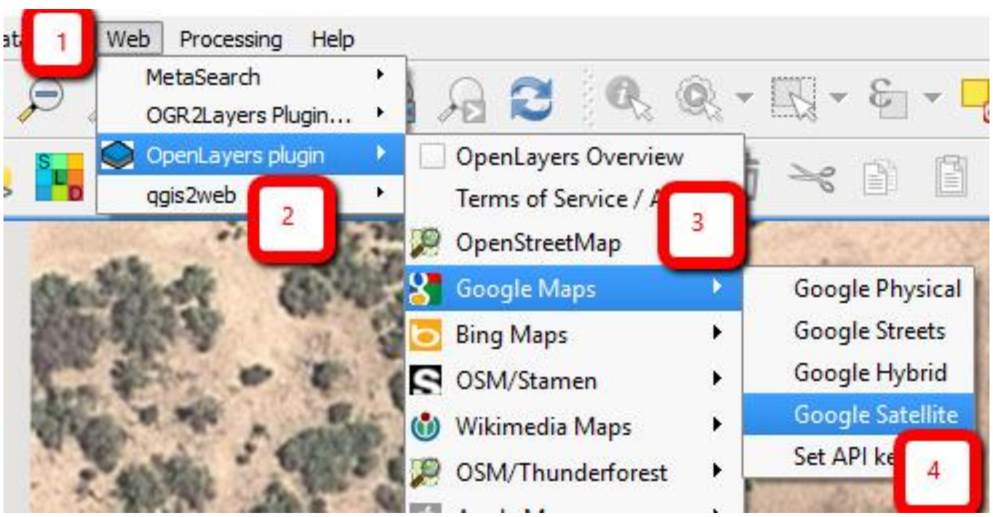
2.1. Create polygon, line and point features

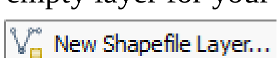
The purpose of this section is to provide guidance on how to create polygons, line, and point also known as vector features using QGIS. These features are one of the input files required for further analysis according to the users' need. The instructions described here were mostly taken from the QGIS User Guide, and adapted to meet our needs of the training.

Input: Any georeferenced image file (samples) or WMS layer containing features you would like to trace. For this practical we will use the Google satellite image, to do so, we need to add the OpenLayers Plugin.

1. Go to *Plugins > Manage and Install Plugin* and type OpenLayers Plugin. Then Click install. Other forms of adding images are through (*Layer > Add layer > Add Raster Layer*) or WMS layer (*Layer > Add Layer > Add WMS Layer*).

2. Then click on *Web > OpenLayers Plugin > Google Maps > Google Satellite*, then zoom to the area of interest.

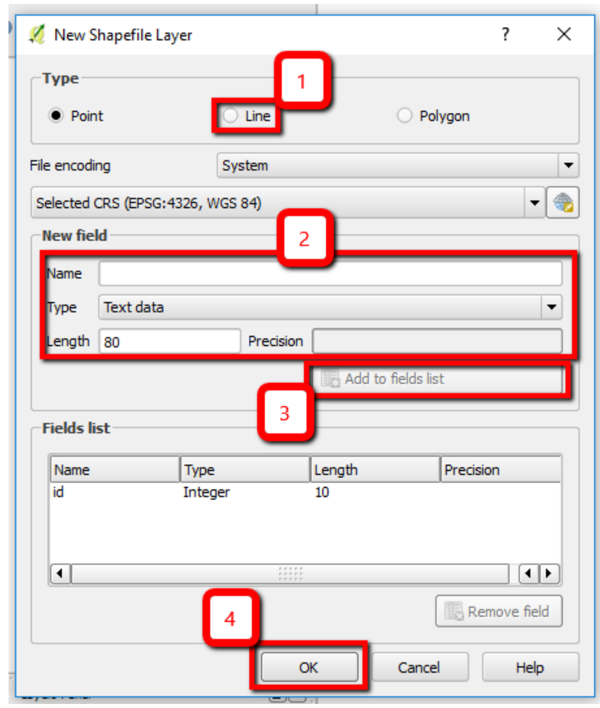


3. To create the new empty layer for your vector feature; select *Layer > Create Layer > New Shapefile Layer*. 

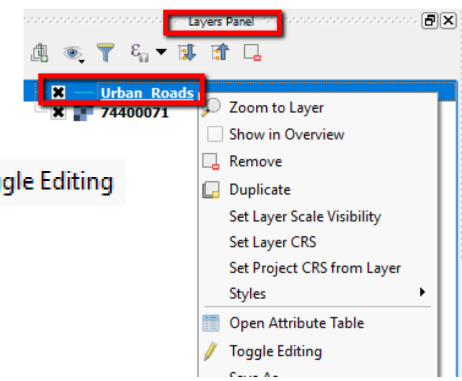
You will be prompted to confirm the **Type** of feature you want to create (point, line, or polygon). By default, the Coordinate Reference System used is *WGS 1984* (read more), but you can change this if you wish. 

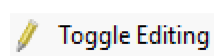
4. You will then be prompted to give:

- ✓ The **Name of the Attribute** you are tracing e.g. Name, Type, Code etc.
- ✓ The **Type** of the Attribute – e.g. Text, Whole Number
- ✓ The **Width** of the field for the Attribute. Select Add to Attribute list
- ✓ The **Shapefile Name** to save the layer.



4. The shapefile will be added to the **Layers Panel** on the left hand side. *RIGHT click* on the layer (*streams or rivers*) to bring up a menu of options connected to it.

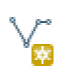


5. To add or edit features, select the *Toggle editing*  or from the top main tool bar 

6. For capturing POINTS

- ✓ Click on the point button 
- ✓ Click points at your chosen location, and choose a name for each point feature
- ✓ Click on Toggle editing to save the vector point layer

7. For capturing **LINES**

- ✓ Click on the point button 
- ✓ Click a set of points along the line. RIGHT click when you have reached the final point to finish, and choose a name for the line feature
- ✓ Click on Toggle editing to save the vector line layer

8. For capturing POLYGONS

- ✓ Click on the point button 
- ✓ Click a set of points along the perimeter of the polygon. RIGHT click when you have reached the final point to finish, and choose a name for the polygon
- ✓ Click on Toggle editing to save the polygon layer

9. For editing points, lines and polygons:

- ✓ The Move Feature button  allows a whole feature to be moved to a new position
- ✓ RIGHT click on the layer in the Table of Contents and select Open attribute table to view and edit the information connected to the features
- ✓ RIGHT click on the layer in the Table of Contents and select Save As to save the layer in a number of formats, including Keyhole Markup Language (KML).

10. You can save your current open layers and features at any time by using the Save Project button. 

NOTE: ***Output options:*** *A shapefile or (Keyhole Markup Language) KML file with vector features. A shapefile actually consists of several files (more info). The following three are required:*

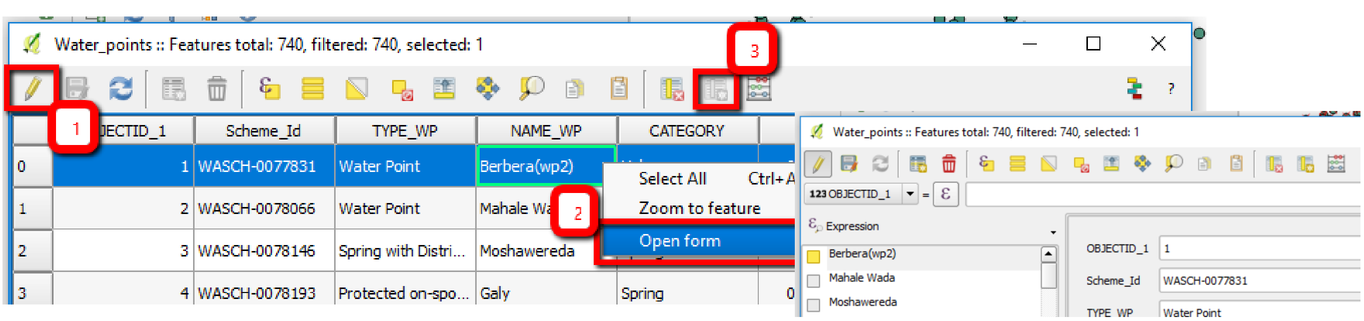
1) .shp file containing the feature geometries
2) .dbf file containing the attributes in dBase format
3) .shx index file
4) .prj file contains the projection information (# not mandatory)

KML is a file format used to display geographic data in an Earth browser such as Google Earth.

2.2.2.2. Create attribute tables to features/Populate data

One way to create attribute table is shown in section 2.1 above as component of creating new shapefiles. You call also add a new field on the existing attribute table to the existing feature class (point, line, and polygon). 

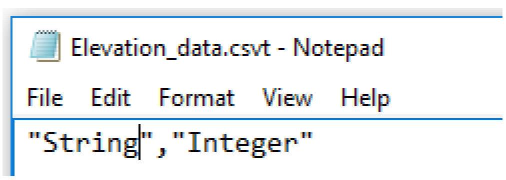
- ✓ Load the vector file (Water_points.shp). Go to *Layer > Add Layer> Add Vector Layer*.
- ✓ Browse to the input data location folder. Select Water_points.shp
- ✓ Right-click on the layer and select Open Attribute Table.
- ✓ Activating the Edit tool and Add a new field after which you can edit accordingly.



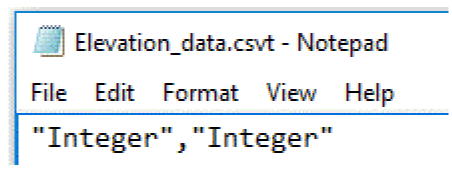
2.3.2.3. Import tables to GIS data layers (Join)

This exercise is to show how tabular data (Elevation_data.csv) to the attribute of a shapefile (Water_points.shp) and then used for further analysis. Read more link.

- ✓ Open the .csv file in a text editor. Examine the attributes of the csv file and identify a unique and common attribute to each (csv file and the shapefile).
- ✓ We could import this CSV file without any further action and it would be imported. But, the default type of each column would be a *String* (text). Having it imported as text would not allow us to run any mathematical operations on the column with numbers. We therefore need to create a sidecar file with a .csvtextension (.csvt) to tell QGIS to import the field as a number. This file will have only 1 row specifying data types for each column. Save this file as the original file but with a different extension (Elevation_data.csvt).



- OR-

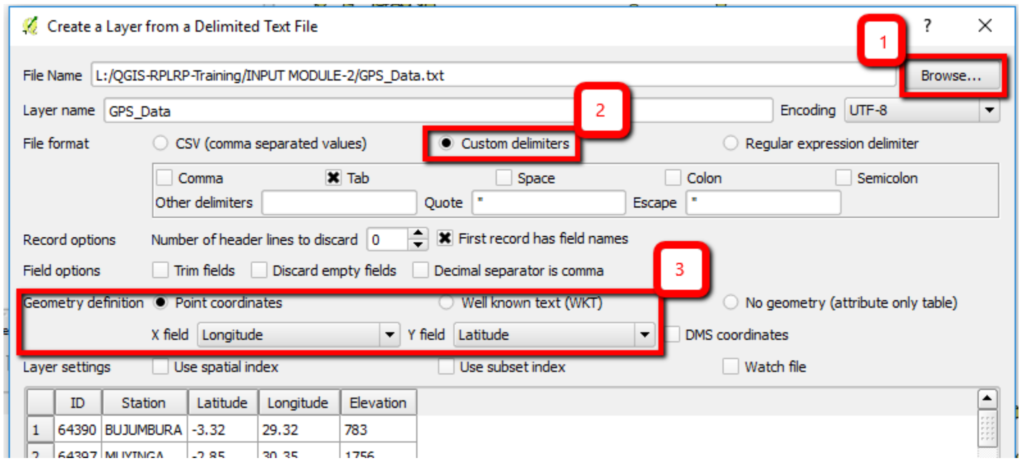


- ✓ Now import the CSV file to QGIS. Go to *Layer > Add Layer > Add Delimited Text Layer*.
- ✓ Browse to the folder containing the CSV file and select it. Since we are importing this as a table, we must specify that our file contains no geometry. Select the No geometry (attribute only table) option. Click OK.
- ✓ Select the Water_point layer, Right-click on it and select Properties.
- ✓ In the Layer Properties dialog, select the Joins tab. Click on the button at the bottom to create a new table join.
- ✓ In the Add vector join dialog, select Elevation_data as the Join layer. Select the fields with unique ids in both the shapefile and the CSV. Then Click Okay.
- ✓ Close the Layer Properties dialog. At this point, the fields from the CSV file are joined with the shapefile. Right-click on the Water_point layer and select Open Attribute Table.

2.4. Import GPS data to GIS format

The GPS data comes in a table i.e. text file. If the data has a list lat/long coordinates, you can easily import this data in your QGIS.

- ✓ Examine your tabular data source if it contains Latitude and Longitude.
- ✓ Click on *Layer > Add Layer > Add Delimited Text Layer* to import the file.
- ✓ In the dialog, click on Browse and specify the path to the text file. In the File format section, select Custom delimiters and check Tab. The Geometry definition section will be auto-populated if it finds a suitable X and Y coordinate fields. In our case they are LONGITUDE and LATITUDE. You may change it if the import selects the wrong fields. Click OK



- ✓ An error may occur as a result of missing X and Y fields. *Just ignore it for purposes of this exercise.*
- ✓ A Coordinate Reference System Selector will ask you to select a coordinate reference system. Select WGS 84. Click OK.
- ✓ The data will be imported and displayed in the QGIS canvas.

MODULE -3: BASIC GEOPROCESSING AND SPATIAL ANALYSIS

3.1. Basic Geoprocessing and Spatial Analysis

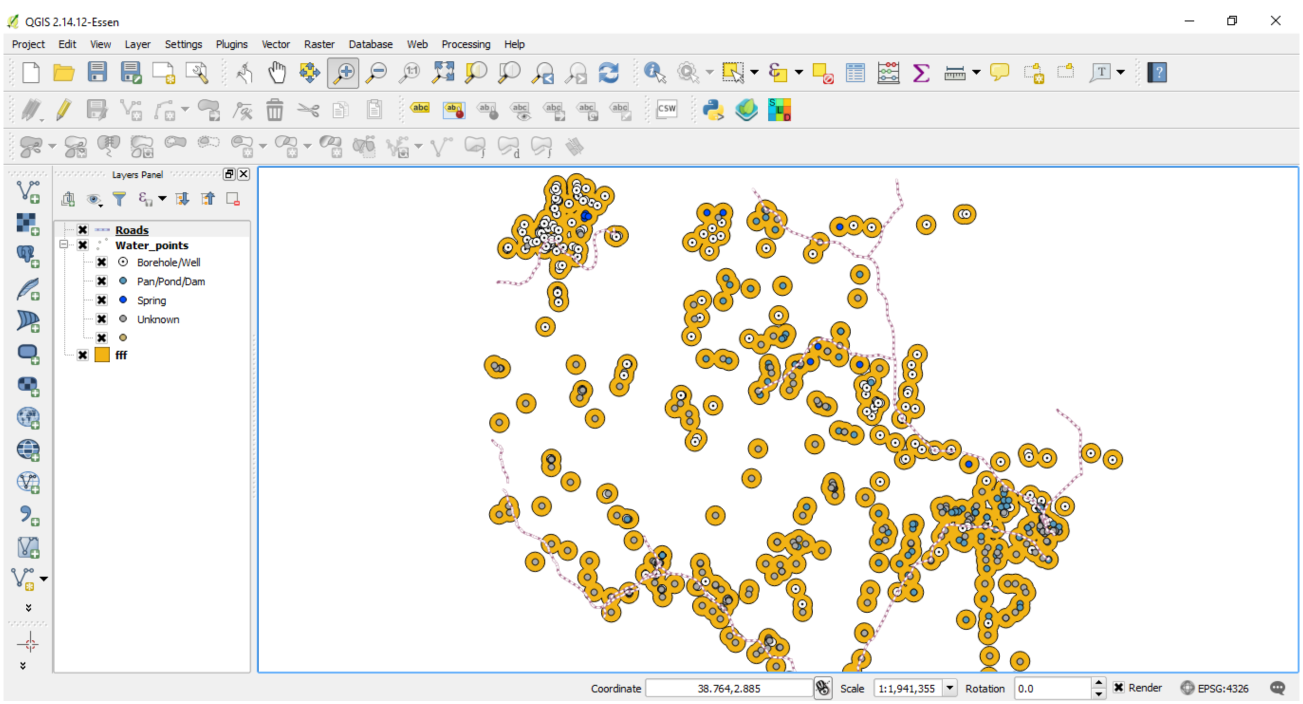
Rational: The main rational for using geoprocessing tools and spatial analysis is to try to answer some space based questions and get more information out of your data.

Geoprocessing is a GIS operation used to manipulate spatial data. A typical geoprocessing operation takes an input dataset, performs an operation on that dataset, and returns the result of the operation as an output dataset. All data preparation and manipulation can be called Geoprocessing. We will see some of the most important tools under this topic which really helps you answer spatial questions.

a) Buffer Analysis

Buffer analysis is one of the most important geoprocessing tools that help to identify proximity of places from a reference layer. For instance, if you wish to identify road networks with in 3km of **water points** you can easily identify them. Let's create a buffer of 3 km from a water point's data and see which roads give acess to the nearest water points.

1) Add **Water points** data layer from ***C/RPLRP_GIS/* folder**
2) Under the main menu go to **Vector** > **Geoprocessing Tool** > click **buffer**
3) Set **Water points** as input layer and since the data is in Geographic coordinate give 0.05 iunder distance which is approx... 5km buffer.
4) save it under your **My-Work** under ***C/RPLRP_GIS/ folder*** with file name **5km buffer.shp**
5) Zoom-in to the stations to see the buffer around the stations



 What if you want a different buffer distance for each based on certain value like type of water source? OR You want to create highly accessible, Accessible and inaccessible map depending on distance?

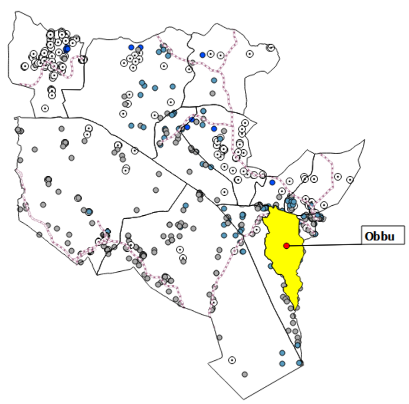
b) Intersect

This tool is one of the essentials in GIS and helps to get not only the common areas between two layers but also to juxtapose the attribute information of one layer next to the other. Example, all the **Water Points** data have category. So, if you wish to know the county/zone of each of the points you can interest the water points with Cluster 2 layer.

1) Load **Cluster 2** and **Water points** layer in to QGIS
2) Go to **Vector** > **Geoprocessing Tool** > click **Intersect**
3) Set the first Input vector layer **Cluster 2** and in the second **Water points**
4) Save it under **My-Work** folder with file name **Intersect.shp**
5) Now you can open and see that the attribute table contains County information for all stations

 **Can you categorize stations based on the county/Woreda one they are located in?**

c) Clip



This is a famous tool to clip any of your spatial data (vector) with in your area of interest. Just as an example let's clip the **Water Points** that are found in Obbu sub county in Kenya from Cluster 2. The procedures are as follows

1) Use the select tool icon  in QGIS and select **Obbu.shp**
2) Once you select go to **Vector** > **Geoprocessing Tool** > click **Clip**
3) Set **Water points** as ***input vector layer*** and **Cluster 2** as ***Clip layer***
4) Tick the **"use only selected feature"** under Cluster 2 to limit clipping boundary to **Obbu**
5) Save it under **My_Work** folder with **Obbu water points.shp** file name

There are hundreds of geoprocessing tools in QGIS and all of them are designed to help you manipulate your spatial data to reach at certain results or simple make analysis of your data to make more meaning out of it depending on your need.

Tip! You can add a base map to your layer by activating **<u>Open layer plugin</u>** from **<u>Web</u>** in the main menu

3.2. Spatial Analysis

The rationale for spatial analysis science is to understand spatial distribution, variation, interaction and relationships of features or phenomena. According to Carleton College definition spatial analysis is a set of techniques for analyzing spatial data. The results of spatial analysis are dependent on the locations of the objects being analyzed. Software that implements spatial analysis techniques requires access to both the locations of objects and their attributes. The other description is from ESRI "Spatial analysis is how we understand our world—mapping where things are, how they relate, what it all means, and what actions to take. From computational analysis of geographic patterns to finding optimum routes, site selection, and advanced predictive modeling, spatial analysis is at the very heart of Geographic Information System (GIS) technology."

The goal of spatial analysis is to answer spatial questions which might be related to location, pattern, change, scenarios and others. GIS softwares are designed to provide a state of the art tools to process data and answer such complex space based questions.

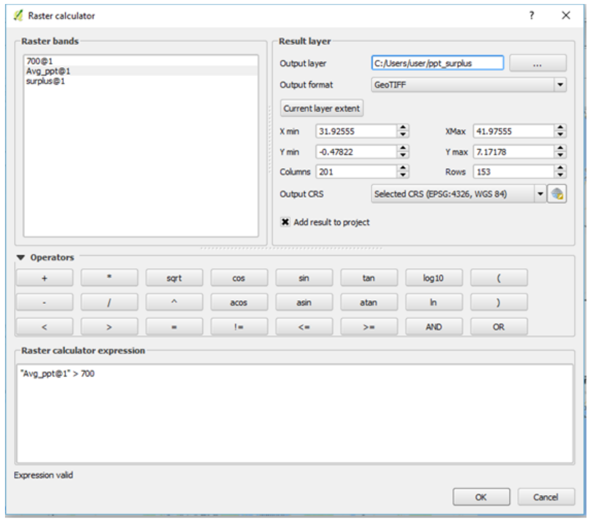
There are hundreds of tools under the QGIS toolbox to help you carry out spatial analysis, however, it is very very important to first design a methodology or s model which needs to be supported with scientific methods to reach at a conclusion.

a) Raster calculator

This is a key spatial analysis tool when you are working on raster data. Almost all of the satellite data are raster based and thus, knowledge of this tool helps to run spatial analysis based on the pixel/cell value. For instance, you may be interested to know areas in your areas of interest that receive rainfall greater than 600 mm or between 300-1000mm a year. Raster calculator is also used to run equations.

Now let's start by identifying areas that receive average rainfall at greater than 600mm to see water deficit or surplus conditions in the region.

1) Open ***Avg ppt.tif*** file under ***C/RPLRP_GIS*** in QGIS
2) Go to **Raster** in the main menu and Click on **Raster calculator**
3) In the dialogue box double click ***Avg ppt.tif*** and click on **'>'** sign and write 700
4) Set the **output** location ***C/RPLRP_GIS/Mywork*** and file name ***ppt_surplus*** and click ***Ok***



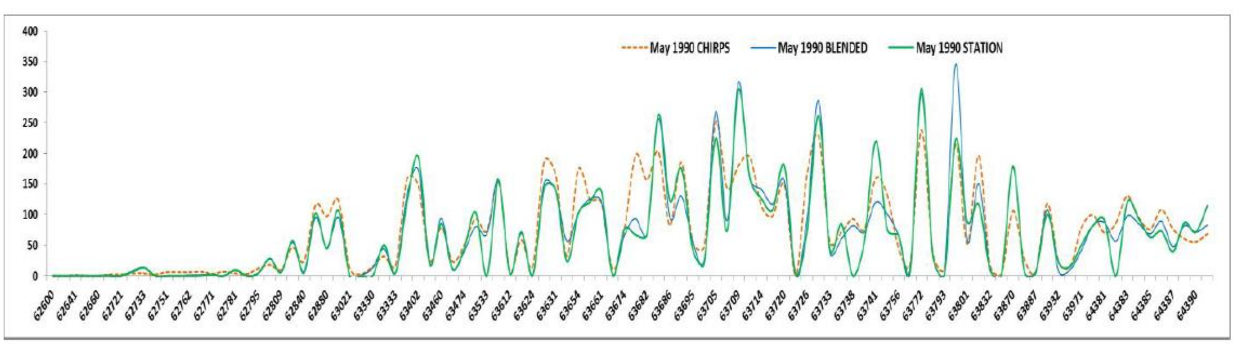
**What if you need areas that received rainfall between 250 and 1000mm?**

d) Extraction of point Values from images based on point station data

This tool is very important when you want to extract data from a raster data set like elevation, rainfall, temperature, etc. The tool extracts pixel values of one or more layers which you can compare to establish some of your hypothesis or use as an input for further analysis.

1) Make sure that the ***Avg ppt.tif*** and ***Water points*** data is still open in QGIS
2) Now go to **Processing** > **Toolbox** > and search ***Add grid values to points***
3) Under points set ***Water points*** and under the ***Grids*** select all
4) In the result set the output file ***grid ppt_points*** under ***C/RPLRP/MyWork***
5) Click **Run** to execute the algorithm
6) Once it finishes right click on the ***grid ppt_points*** and **Open attribute table** to see the results of your operation. You can see the rainfall values for all of the 739 water points.

NB: These values can be compared to the station readings to see the quality of the rainfall estimates from satellite sources. You can also compare the quality of satellite data as compared to station data.



MODULE -4: WEB MAPPING APPLICATION

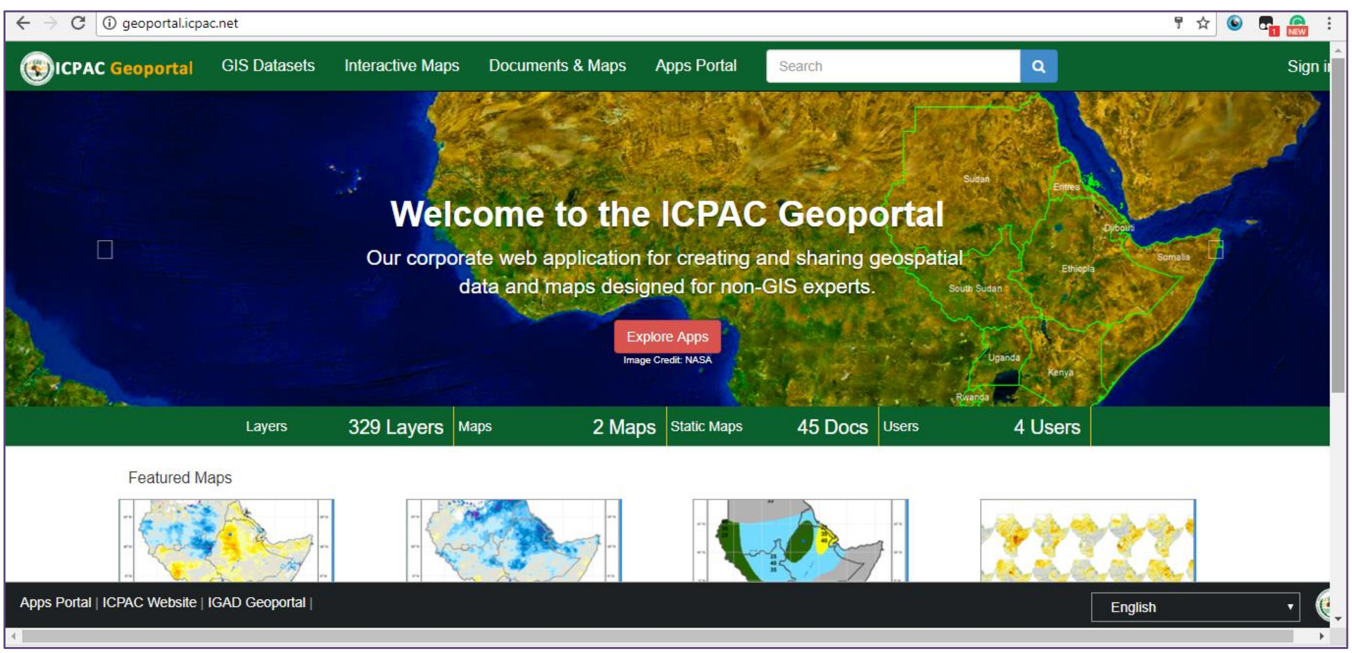
4.1. Introduction to Web Mapping and ArcGIS Online

4.1.1. Introduction to web Mapping and available platforms

Web service, including web maps are resources that allows us to share our resources over the net (inter or intranet). The Desktop GIS helps to produce data layers, analysis and all other intermediately products but sometimes we also want to share your data online for selected user groups or to the whole world. In such case there are commercial and open source platforms which allows you to go online. The most common open source web mapping platforms (often require developer skills), according to **oSGeo** wiki are the following;

(a) **MapServer** (http://www.mapserver.org/)
(b) **MapBuilder** (http://docs.codehaus.org/display/MAP/Home)
(c) **Mapbender** (http://www.mapbender.org/index.php/Main_Page)
(d) **Chameleon** (http://www.dmsolutions.ca/technology/chameleon.html)
(e) **MapGuide** (https://mapguide.osgeo.org/)
(f) **OpenLayers** (http://www.openlayers.org/)
(g) **ka-Map**(http://ka-map.maptools.org/)
(h) **CartoWeb**(http://www.cartoweb.org/)
(i) **deegree iGeoPortal** (http://www.deegree.org/)

For this training, however, we will limit ourselves to the Web GIS platforms available with less developer skill and/or being used at IGAD/ICPAC. The two examples of web mapping platforms available are ArcGIS Online (commercial) and Geonode (Open Source) in addition to hundreds of other customizable open source applications. At ICPAC both of these products are being used due to the respective solutions they provide.



GEONODE based ICPAC Geoportal (Open Source)

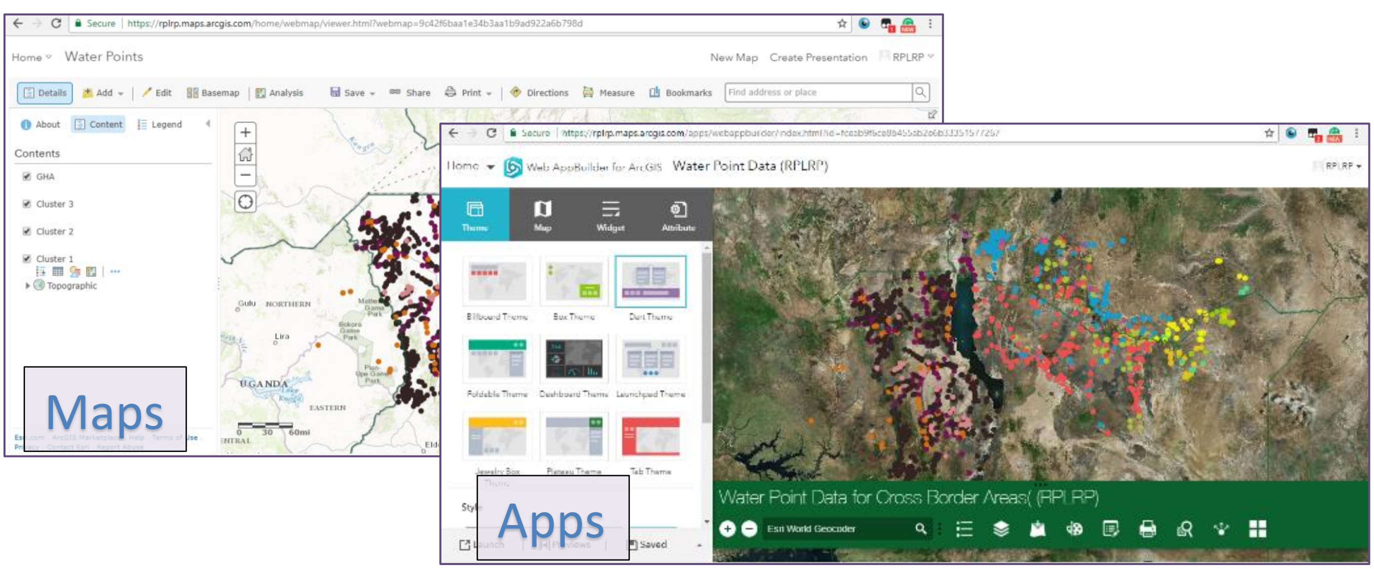
ArcGIS ONLINE based ICPAC Geosptial Apps (Commercial)

4.2. Working on ArcGIS Online Web Mapping Platform

4.2.1. Introduction to ArcGIS online interface

ArcGIS Online is a web mapping platform which allows you to develop a map and apps that supports visualization of geospatial data (raster and vector) files. The major advantage of this platform is that it doesn't require coding or developer skills and also provide charming visualization. The limitation is that it is commercial and limited storage (credit) capacity with basic or even standard subscriptions.

There are two major components to develop a web mapping application; first, maps that allows you to upload and symbolize your data and the second component is what is called "Apps" which provide a platform to design /visualize your maps with different styles, choose widgets and corporate branding. The interface for both are given below



You will be working with maps under section 4.2.2. and if time allows a demonstration of how to design ArcGIS App will be presented.

Now let's get in to the portal!

4.2.2. Access Right and log in to RPLRP portal

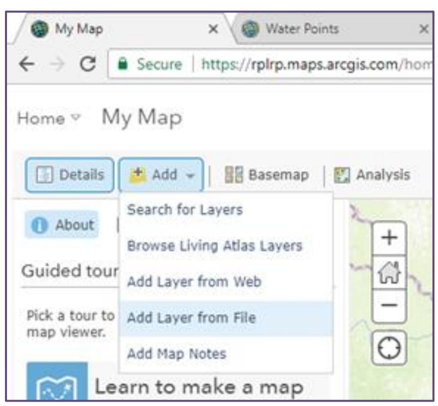
For this Training we have developed a trial RPLRP Web Mapping Application for you to exercise before you start working on the main portal. Follow these steps

1) ***Make sure that you have internet and go to https://rplrp.maps.arcgis.com***
1) You will be asked to give your access credentials and provide User Name: RPLRPGIS and Password: webtraining1 to access the un-official ArcGIS online portal of RPLRP developed for this training.
2) Now click on the home page to go to the interface and click on **Water Point Data (RPLRP)** canvas to launch the water points web application
3) Please explore the features of the web mapping portal and discuss the cons and pros with the facilitator. You can also access the official ICPAC portal here https://icpac.maps.arcgis.com

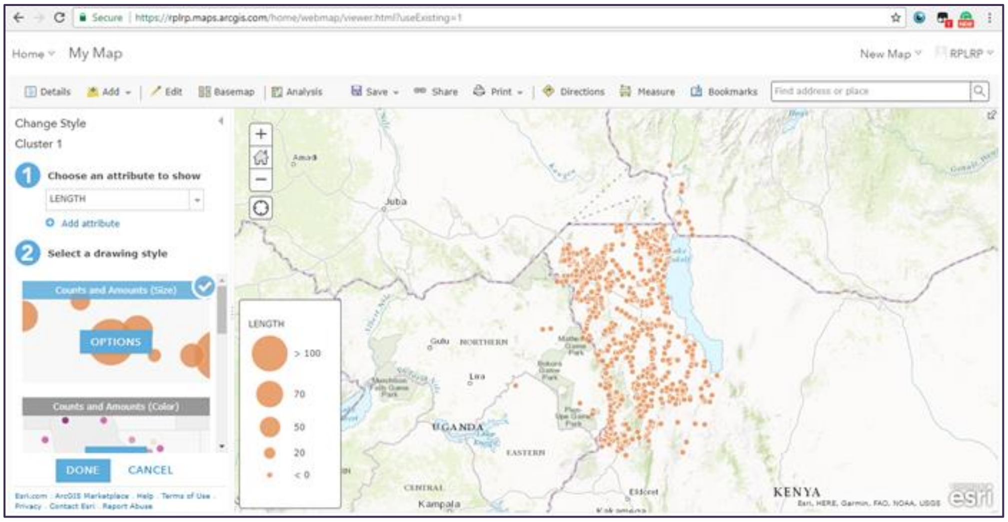
Now all the water point data will be removed and you will exercise on how to upload your GIS files in to a web

4.2.3. Upload your data in to your ArcGIS online

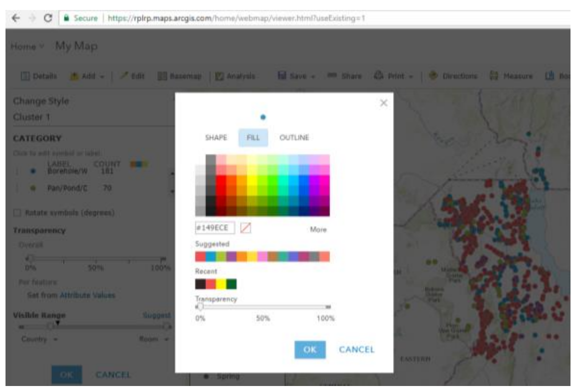
2) You are going to upload your water points to the web platform and the data is available under **C:/RPLRP_GIS/Web** folder
3) Go to maps under the Home menu of the RPLRP training portal and this opens a maps interface of ArcGIS Online
4) Go to **Add** and click on **Add layer** from File



5) Go to **Add** and click on **Add layer** from File and locate **C:/RPLRP_GIS/WebMapping** and select **Cluster 1** to import layer
 (**Remember**: You only can upload zipped shape file, CSV/Txt, GPX file in here)
6) After few seconds your cluster 1 water points will be loaded as something like this



7) Now you can manipulate the symbology in a way that suits your organizational brand or personal feel. Let's work on symbology
8) Click on a drop down menu under ***"Choose an attribute to show"*** and look for **"CATEGORY"** to classify your water points based on the type.
9) Click on **OPTIONS** to manage the color, size and type of symbol you want to assign for each type of water points
10) Click on the points to choose the shape, color and outline for it. Do this for all the four types of water points (Borehole/Well, Pan/Pond/Dam, Spring and Unknown).

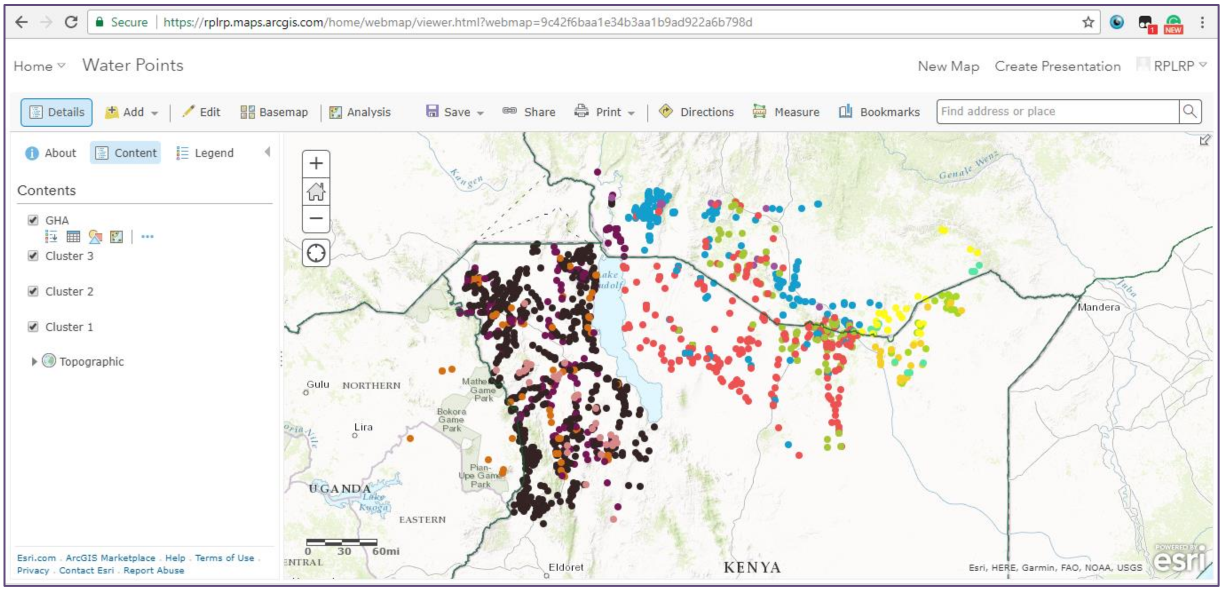


11) You can re-arrange the list by drag/drop to list them in the following order (Borehole/Well, Pan/Pond/Dam, springs and Unknown).
12) Once you are done with that you can hit **Ok** and then **Done** to finish.

 **Please import cluster 2 and 3 also and edit the symbology the way you feel appropriate.**

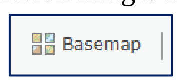
Add Cluster 1, 2 and 3 boundary also.

The Final map looks something similar this

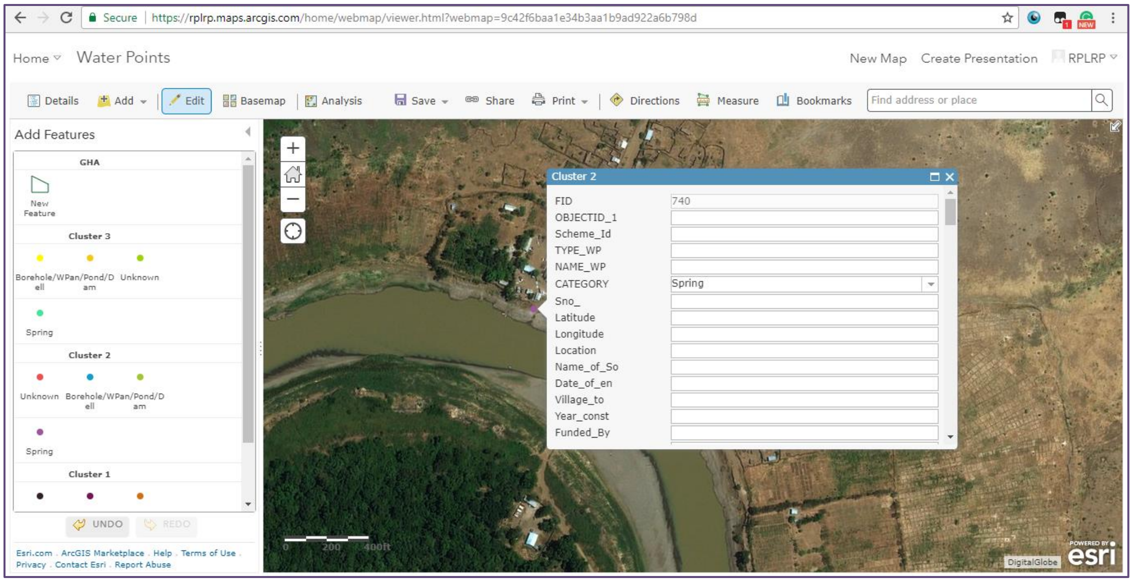


4.2.4. Data Editing in Web Map

For consistency and ease of manipulation it is advisable to edit your data in desktop GIS platform using QGIS or other softwares. It is only when you are sure on your data integrity that you upload it to the web platform. **However**, you might want to edit your data due to addition of new sites or some might have wrong information which you want to correct in your web database. In such case you can edit the hosted service in many ways. Now let's see how to edit water point data which is already hosted on the web.

1) First go to the map you produced in the previous exercise and click on Edit Tool
2) Now you might have local knowledge on location of water points or location of water points map from other sources, or you can see surface water from high resolution image. If your information is from the last source, you can select imagery from the Basemap 

 and zoom to see the location of Pan/Pond/Dam. If you see any discrepancy that means you need to **Add new** or Snap the existing water points to its correct position. Now let's start by Adding a new ones.
3) After you click on Edit and Zoom-in to your area of interest, select cluster 1 springs layer. This means you want to Add new water point which is a spring in Cluster 1. So, zoom to any visible river and click to add new water point source with attribute detail (Use your personal dummy information).



What if the Water point category is marked as Bore hole but you have found out that it is a Pond? How can you edit this?

You can select the point by holding **Ctrl** key and carefully click on the point, the table should open allowing you to change from one type to the other and also edit other attribute information.

4.3. Updating the RPLRP Water Point Data Portal

This training is organized to task you for the following activities once you go back to your duty station;

Activity 1: **Verify the water point types and Locations for your Country**

Activity 2: **Add new water point data which is not captured already**

Activity 3: **Modify any information which is not correct in the database**

Reference

QGIS User Guide Release 2.14 (5th July, 2017) http://docs.qgis.org/2.14/pdf/en/QGIS-2.14-UserGuide-en.pdf