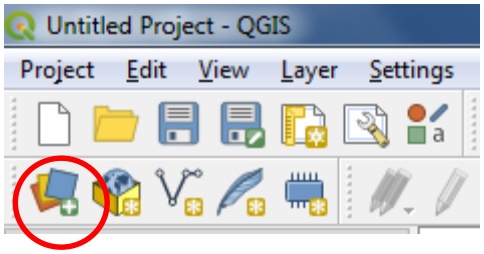
A basic tutorial on QGIS applications in meteorology

1. Digitization: drawing forecast polygons

Polygon drawing is a typical operation in weather and climate analysis. With the advance and availability of GIS software, producing forecast maps with GIS application has become more convenient. The objective of this section is to produce a forecast map with multi-category polygons using QGIS.

The long-term release (LTR) version of QGIS is available at the URL: https://qgis.org. It is assumed that the user is able to download and install QGIS on his/her computer.
In this tutorial, the LTR QGIS version 3.4.2 (Madeira) is used.

First, launch QGIS. We need a basemap layer. Second, import the *WMO_basemap.zip* data that comes with this tutorial. To do so, click the *Open Data Source Manager* toolbar

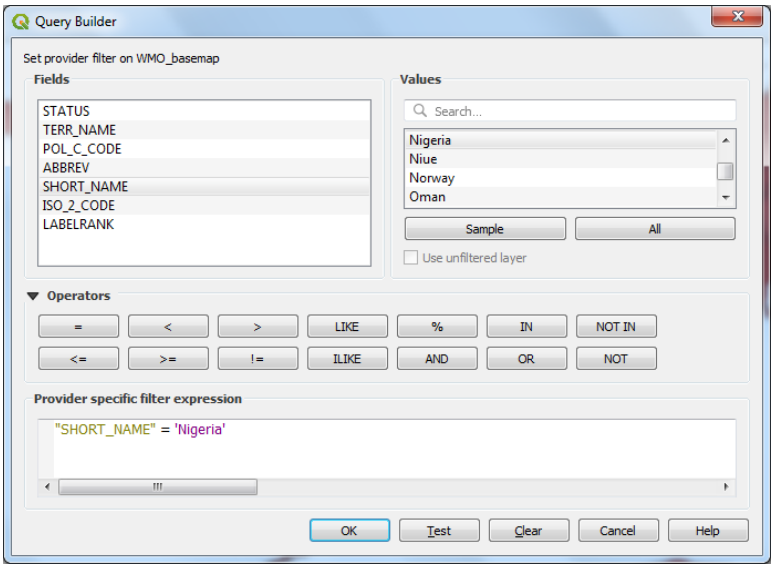


or *CTRL + L*, double-click *WMO_basemap.zip*, and double-click *WMO_basemap.shp*. A worldmap should now appear in the canvas. Close the *Open Data Source Manager* window.

We are going to draw our forecast polygons over a given country. In our case, it is Nigeria.

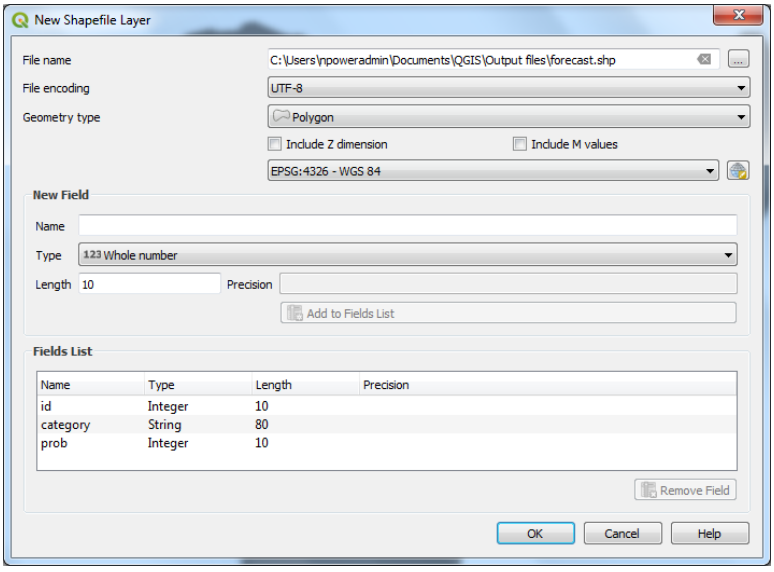
Right-click on *WMO_basemap* layer in the *Layers* panel, located to the left of the window. Click *Filter*. The *Query Builder* window should now appear. Select *SHORT_NAME* in the *Fields* section on the left of the window. Click *All* in the *Values* section to the right of the window. A list of countries should show up in the *Values* section. Double-click *CNTRY_NAME*, click the *equal* sign in the *Operators* section. Scroll down the list of countries in the *Values* section and double-click *Nigeria*. The window should look like the figure below. Click *OK*. The map of Nigeria should now appear in the canvas. Right-click

on the *WMO_basemap* layer and click *Zoom to Layer*. The map should now zoom in and focus over Nigeria.

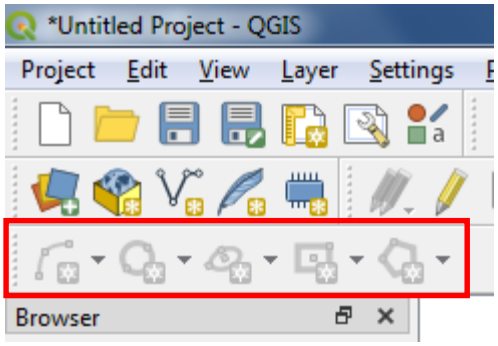


Depending on your preference, you may change the color of the Nigeria map to grey. Right-click on the *WMO_basemap*, hover your cursor over *Styles*, and select grey *#808080*.

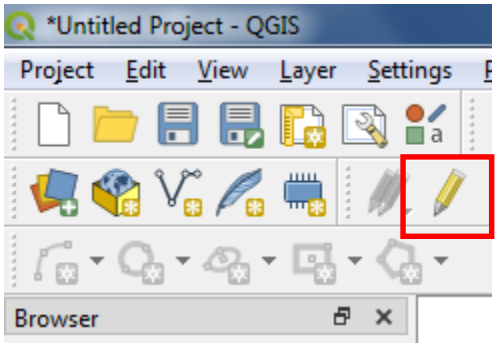
The next step is to create a new and empty shapefile layer. Go to menu *Layer > Create Layer > New Shapefile Layer*. In the *New Shapefile Layer* window box, under *File name*, save the new layer as *forecast* in your preferred directory. Choose *Polygon* in the *Geometry type*. In the *New Field* section, type *category* in *Name*. *Category* would differentiate our planned polygons as above-average or below-average. Make sure that *Type* is *Text data*. Next, click the *Add to Fields List* button. Category should now appear in the *Fields List* section.



Repeat the above step; but type this time *prob*, indicating probability in *Name* in the *New Field* section. Change *Type* to *Whole number*. Click *Add to Fields List* button and verify that *id*, *category*, and *prob* are in the *Fields List*. Click *OK*.



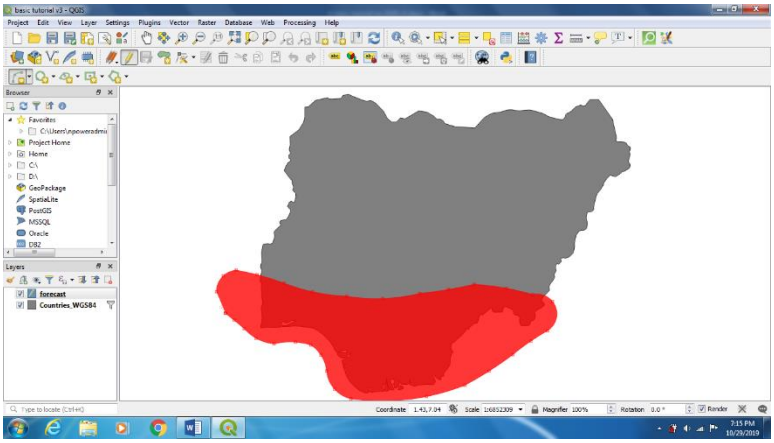
We are now ready to draw our first polygon. But, first, let's add some additional toolbars to our QGIS editor. Click on menu *View > Toolbars > Shape Digitizing Toolbar*. New but inactive toolbars should now appear on the toolbar menu.



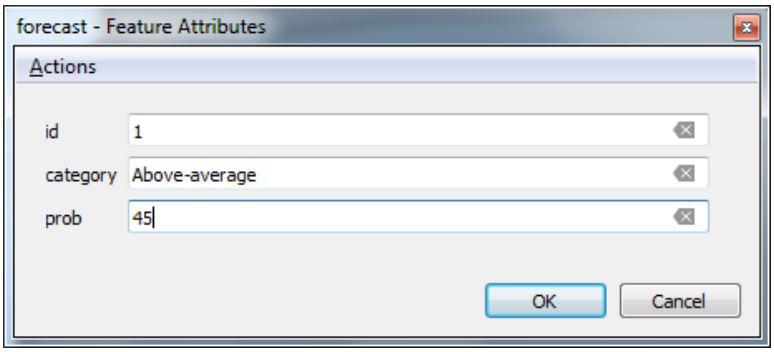
To edit our polygons, click on the *Toggle Editing*, yellow pencil, toolbar. Once this *Toggle Editing* is clicked the digitizing toolbars become active.

To draw a curved polygon, click on the *Add circular string* toolbar. This toolbar allows the user to draw a smooth and curved polygon by adding more vertices (nodes) automatically. Please note that a polygon is drawn by clicking on a starting vertex (node) and moving the cursor to the next one and so on. When satisfied with the shape, right click near the starting vertex to close the polygon.

We are going to draw an above-average polygon over southern Nigeria and parts of the Atlantic Ocean. Start by clicking the first vertex over the ocean to the southwest of Nigeria. Click the next vertices while making a curve, continue, and repeat where a curved shape is needed. The user may have a polygon shape like the figure below right before the last vertex. Close the polygon.



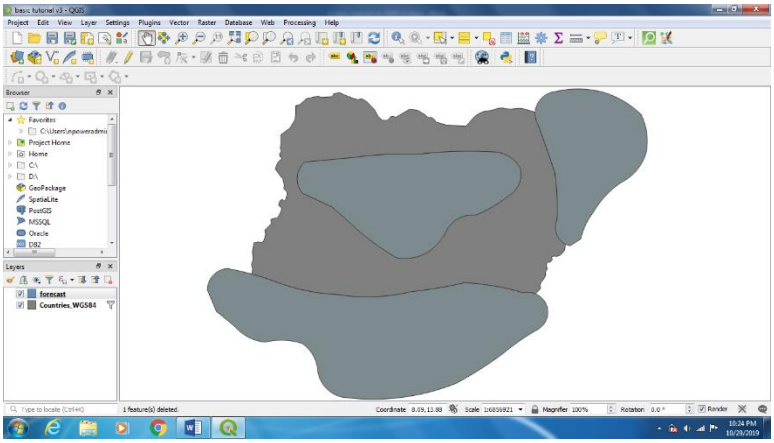
Once the polygon is closed, a new form window pops up. This step consists of filling up the *id*, *category*, and *probability* that describe the first polygon. Type *1* in the *id* fields. Type *Above-average* and *45*, in the *category* and *prob* field, respectively. Then click *OK*. The *Above-average* polygon should now appear over southern Nigeria.



Next, we are going to draw a *Below-average* polygon across central Nigeria. Repeat the above steps from clicking the *Add circular string* toolbar, clicking the vertices, closing the polygon, to filling out the form. This time, type *2*, *Below-average*, and *55* in the *id*, *category*, and *prob* fields, respectively. Click OK. The *Below-average* polygon should now be visible over central Nigeria.

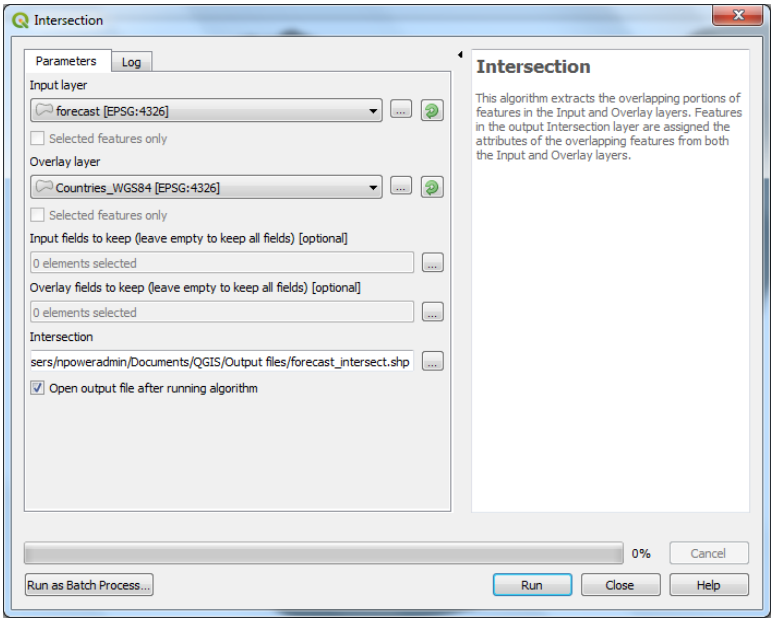
We may add another *Above-average* polygon that covers northeastern Nigeria and also parts of Cameroon, neighboring country. We draw the polygon in a manner similar to the first *Above-average* polygon over southern Nigeria. This time, type *3*, *Above-average*, and *50*, as *id*, *category*, and *prob*, respectively. Click *OK*.

We are now ready to save the polygons under the forecast layer. Click the *Toggle Editing* back and click *Save*. You now may have a forecast map with 3 polygons similar to the figure below.



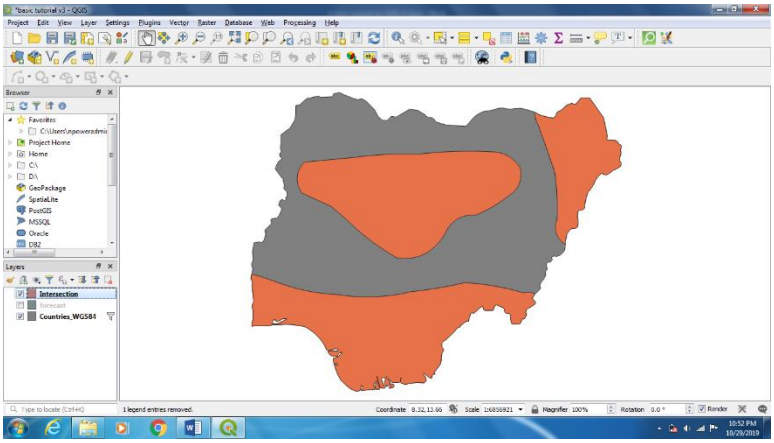
In most cases, it is desirable to have the polygons follow the country outline. QGIS has **vector geoprocessing** to do just that. Go to menu *Vector > Geoprocessing Tools > Intersection*. In the *Intersection* window, select

forecast as *Input layer*. Select *WMO_basemap* as *Overlay layer*. In the *Intersection* field, click … and save the output layer as *forecast_intersect* and as a shapefile (SHP) in your preferred directory.



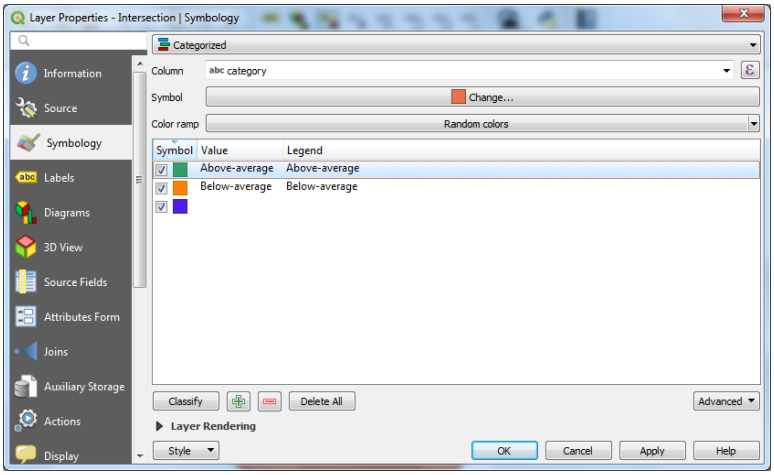
Click *Run*. You should now see that the forecast polygons follow the country outline and are added as a new layer, called *Intersection* in the *Layers* panel.

You may uncheck the box in front of the original forecast layer to make this layer disappear. You then may have a forecast map similar to the below figure. Please note that the polygons 'default color may be different.



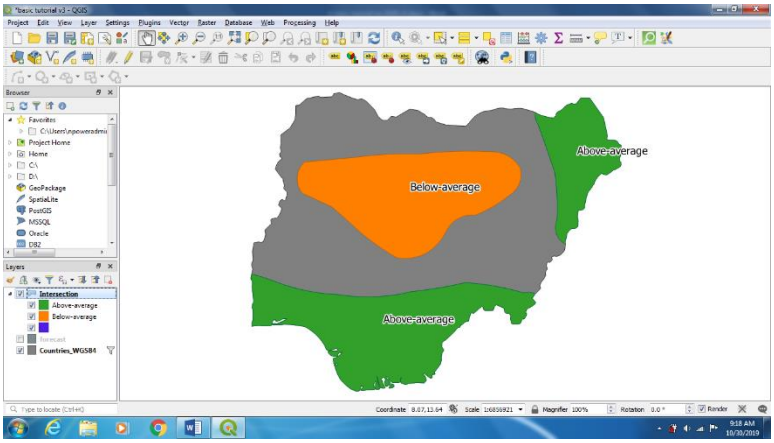
Since the forecast polygons are undistinguishable from one another, **symbology** enables the user to classify the forecast. To do that, double-click the *Intersection* layer. The *Layer Properties* window should appear. Make sure that *Symbology* is selected on the left tab.

Click the down-arrow to the right of *Single symbol* on the first line to the right of the window and select *Categorized*. Click the down-arrow to the right in the *Column* field and select *category*. Click the *Classify* button to the left of the + and – signs. Double-click and change the color for the *Above-average* and *Below-average* to green and brown, respectively.



Please also note that the user has a lot more controls with other properties such as *Fill color*, *Fill style*, *Stroke color*, etc. by clicking on *Simple fill* in the *Symbol Selector* window after double-clicking the color. Click *OK* to apply the color changes.

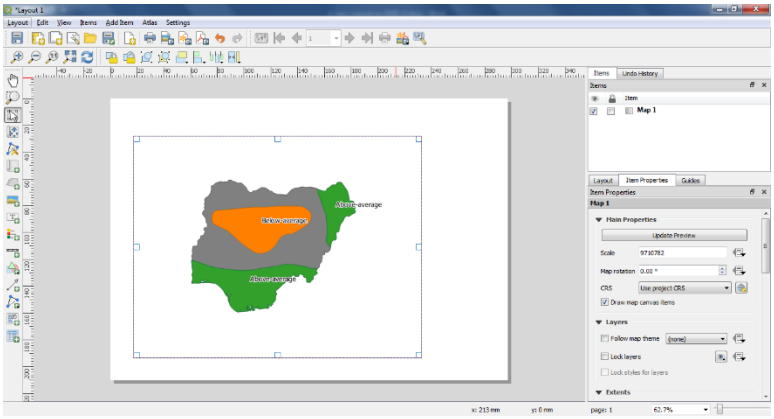
Keeping the *Layer Properties* window open, click on *Labels* on the left tab. Click on the down-arrow to the right of *No labels* and select *Single labels*. Click on the down-arrow in the next line with *Label with* and select *category*. Click on *Text* below the *Lorem Ipsum* section and change *Size* to *14*. Click *Buffer* under *Lorem Ipsum* and check *Draw text buffer*. Click *OK*. You should now have a map similar to the figure below.



So far, we have our forecast map; but certain elements such as title, scale map, legend, north arrow, etc. may be missing. These could make the map easier to understand and interpret for the intended users . The **mapping** process enables the user to perform this task.

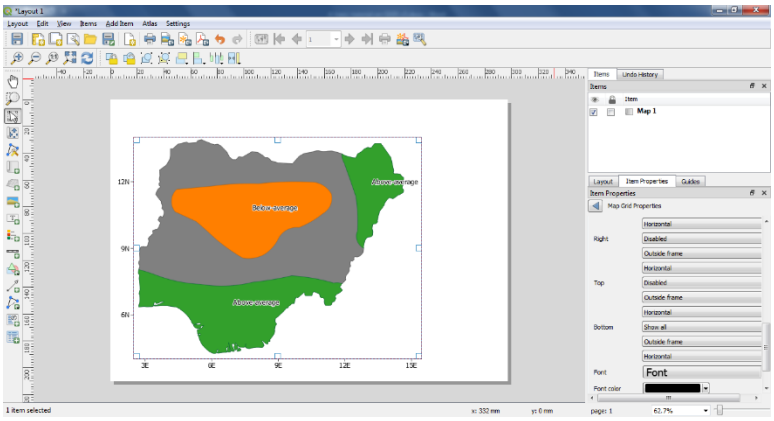
Go to menu *Project > New Print Layout* or *CTRL + P*. The *Create print layout Title* window should appear. Click *OK*. A new *Layout 1* window should appear. Maximize the window. Click on the down-arrow at the bottom right and select *Fit Layout* to fit the screen.

To add the map to the layout, go to menu *Add Item > Add Map*. Drag a rectangle on the layout by starting with the top left corner and leaving some margins for the title, coordinates, legend, etc. The forecast map from the QGIS editor should now appear on the layout.



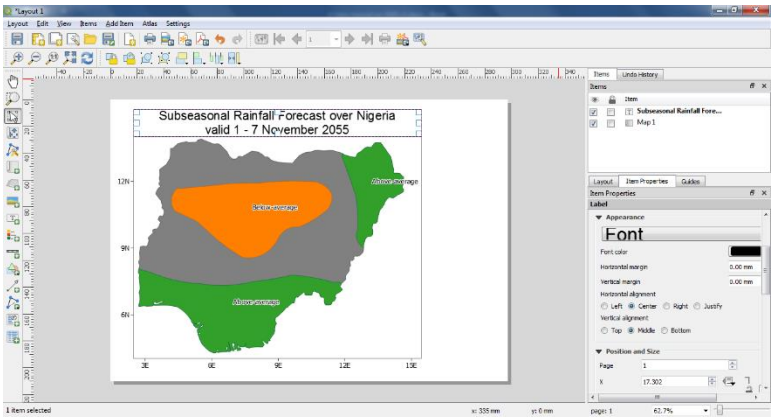
The size of Nigeria inside the map area may be too small. On the *Item Properties* tab to the right of the window, change the *Scale* to *6,000,000* or until an adequate size is obtained.

To add coordinates and frame to the map, scroll down the *Item Properties* and click *Grid*. Click the *+* sign. Select *Grid 1* and click the *Modify grid* button. In the *Appearance* section, in the *Grid type*, click the down-arrow and select *Frame and annotations only*. In the *Interval*, change *X* and *Y* to both *3*. In the *Frame* section, change *Frame style* to *Exterior ticks*. Scroll down and deselect *Right side* and *Top side*. In *Draw coordinates* section, change *Format* to *Decimal with suffix*. Change *Right* to *Disabled*. Change *Top* to *Disabled*. Click *Font* and change *Size* to *14*. Change *Coordinate precision* to *0*. Click on the *Go back* button to the left of *Map Grid Properties*. Scroll down and check *Frame*.The coordinates should now appear like in the figure below.

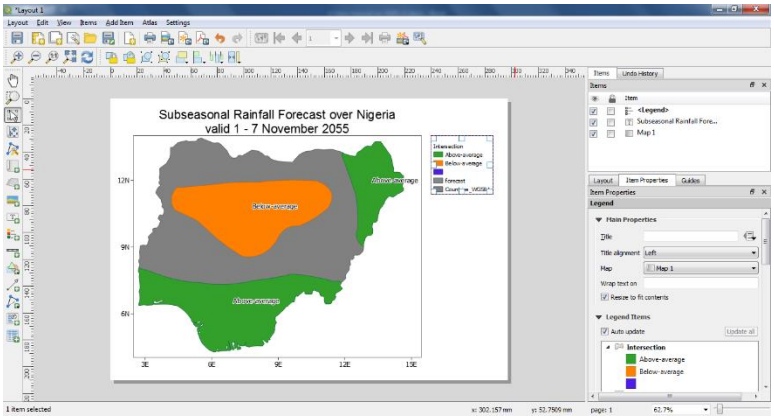


To add title to the map, go to menu *Add Item > Add Label.* Drag a rectangle on top of the map area. A box, with the text *Lorem Ipsum* should appear. Go to the *Item Properties* tab on the right, under *Main Properties*, replace *Lorem Ipsum* with *Subseasonal Rainfall Forecast over Nigeria*. Hit Enter for next line. Write *valid 1 – 7 November 2055*. Under *Appearance*, click *Font* and change *Font* to

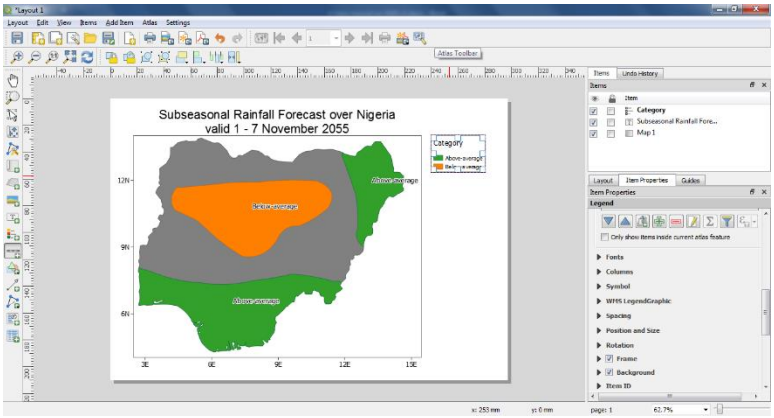
Arial and *Size* to *26*. In the *Horizontal alignment* and *Vertical alignment*, select *Center* and *Middle*, respectively. If the title box is too small, you may adjust the *Height* to an adequate size under *Position and size*.

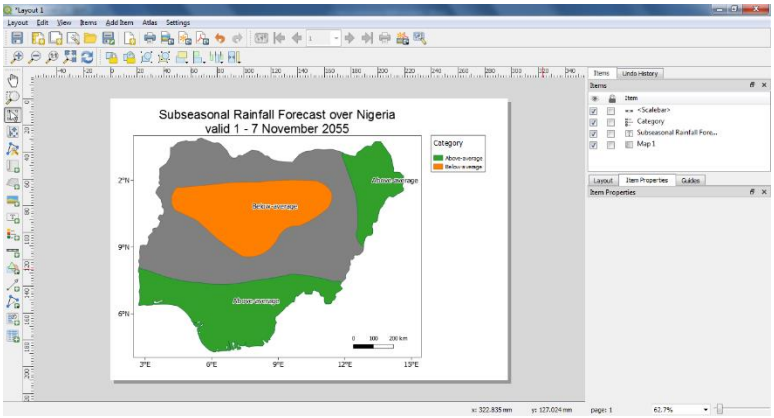


To add legend, go to menu *Add Item > Add Legend.* Drag a rectangle to the top right of the map. All layers in the QGIS editor will appear in the legend. The user can remove and change items on the legend. On the *Item Properties* tab, under *Main Properties*, type *Category* as *Title*. In the *Legend Items* section, uncheck *Auto update*. Scroll down to show the *+* and *-* sign toolbars under *Legend Items*. Click the extra-color (blue in this tutorial) under *Intersection* layer, hold *CTRL*, click *forecast* layer, hold *CTRL*, then click *WMO_basemap*. Click the *-* sign to remove these selected items. Click the *yellow pencil* toolbar, delete *Intersection*, and click *OK*. Scroll down on *Item Properties* and check *Frame*.



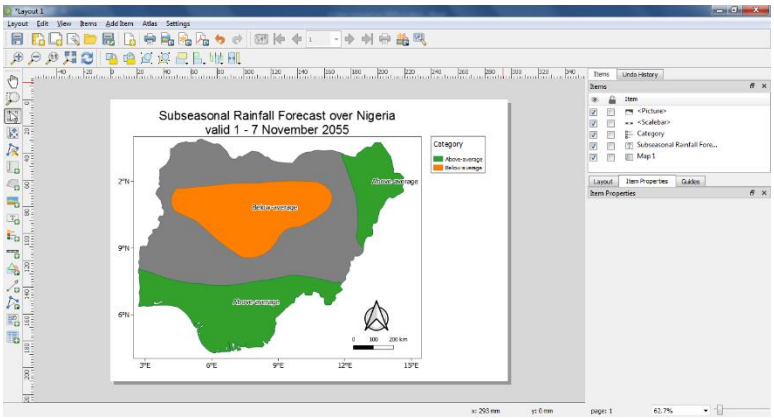
Go to the QGIS Editor and make sure that *CRS* is *WPSG:4326* (*WGS 84*). If not, click on the small *globe* button on the lower right of the window. In the *Project Properties* window,





select *WGS 84* and click *OK*. Go back to the *Layout 1* window. To add scale bar, go to menu *Add Item > Add Scale Bar.* Drag a rectangle to the bottom right of the map area. A scale bar should show up over the designated area.

To add north-arrow, similarly, go to menu *Add Item > Add Picture*. Drag a rectangle above the scale bar. On the *Item Properties* to the right, expand *Search Directories*. Select the north-arrow of your choice.



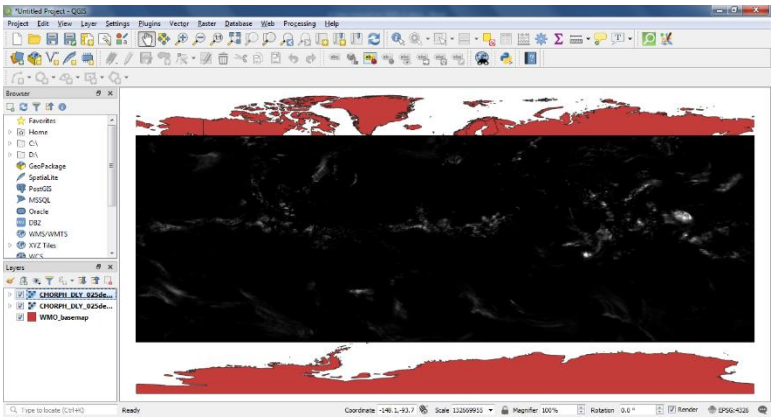
Other elements can be added to or modified on the map. When satisfied, export the map to your preferred location. Go to menu *Layout > Export as Image* or *Export as SVG* or *Export as PDF* according to your preference.

2. Raster operations

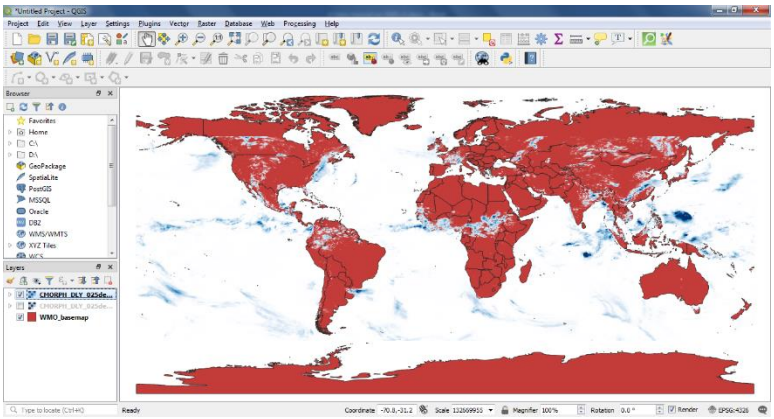
Many weather and climate data are nowadays available in GIS raster format. Raster data are gridded and georeferenced data. The objectives of this section are to perform mathemathical operations and clipping analysis on satellite rainfall estimate data.

Use the *Open Data Source Manager* toolbar or *CTRL + L* to load in *WMO_basemap, CMORPH_DLY_025deg_20140704_float*, and *CMORPH_DLY_025deg_20140705_float,* raster data that come with this tutorial. By

default, raster data are displayed in grayscale like in the figure below. Change the symbology of



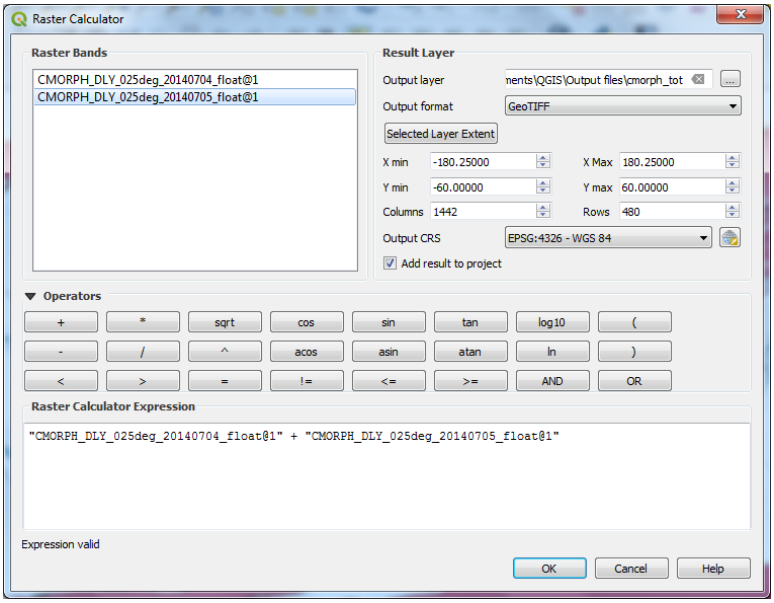
CMORPH_DLY_025deg_20140704_float by double-clicking the layer on the *Layers* panel. In the *Layer Properties*, under the *Band Rendering* section, change *Render type* to *Singleband pseudocolor*. Change *Max* to *100*. Under *Min / Max Value Settings*, change *Color ramp* to *Blues*. Double-click the color that is associated with the *0* mm value. The *Change Color* window should appear and set *Opacity* to *0%* and click *OK*. The figure should look like the following figure.



Repeat the same above procedure for *CMORPH_DLY_025deg_20140705_float*.

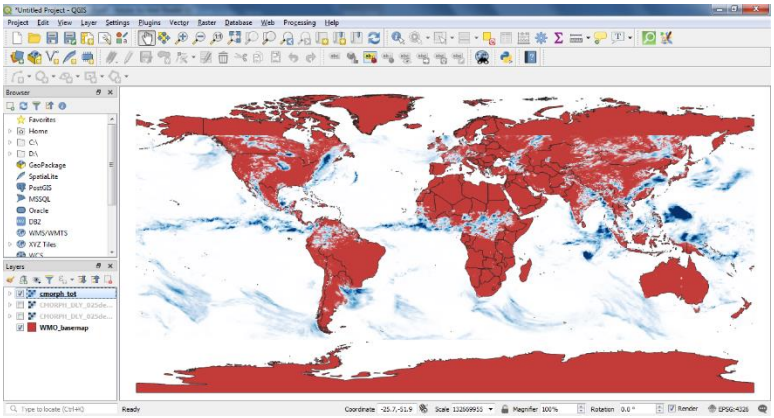
To compute and display the 2-day rainfall totals across the globe, go to menu *Raster > Raster Calculator*. In the *Raster Bands* section, double-click *CMORPH_DLY_025deg_20140704_float@1*. It will appear in the *Raster Calculator Expression* section. Under the *Operators* section, click the *+* sign. Double-click *CMORPH_DLY_025deg_20140705_float@1*. In the *Result Layer* section to the right, save output file as *cmorph_tot* in your preferred location. Click *OK*. The 2-day CMORPH

rainfall totals layer should now appear in grayscale. Change the symbology of *cmorph_tot* using the same properties as those for the

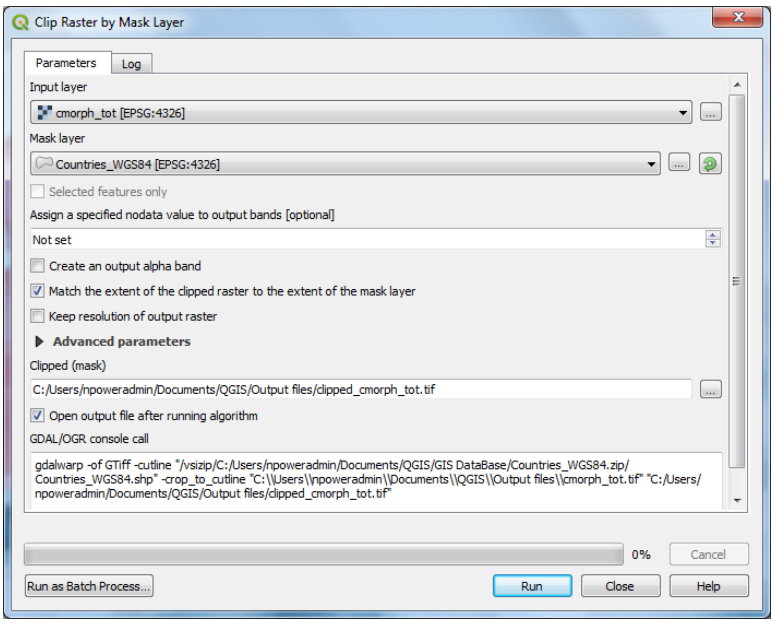


CMORPH_DLY_025deg_20140704_float and *CMORPH_DLY_025deg_20140705_float*. Verify that *cmorph_tot* is indeed the sum of the two original raster data by checking and unchecking the layers to make them visible or invisible.

Now, let's assume we are interested in analyzing rainfall totals over Nigeria only. First, filter the *WMO_basemap,* basemap, layer to show Nigeria only.



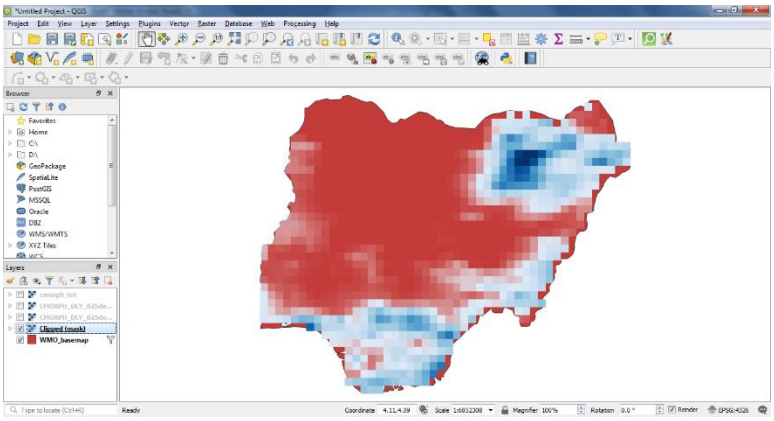
To crop *cmorph_tot* over Nigeria, we use the QGIS **clipping** function. Go to menu *Raster > Extraction > Clip Raster by Mask Layer*. In the *Clip Raster by Mask Layer* window, make sure that *Input layer* is set to *cmorph_tot* and *Mask layer* is set to *WMO_basemap*. In the *Advanced parameters* section, under *Clipped (mask)*, click … to the right and save the output file as a file as *clipped_cmorph_tot*.



Click *Run*. The clipped layer should now appear. Change the symbology of *clipped_cmorph_tot,* using same properties as before. The clipped layer may then look like the figure below.

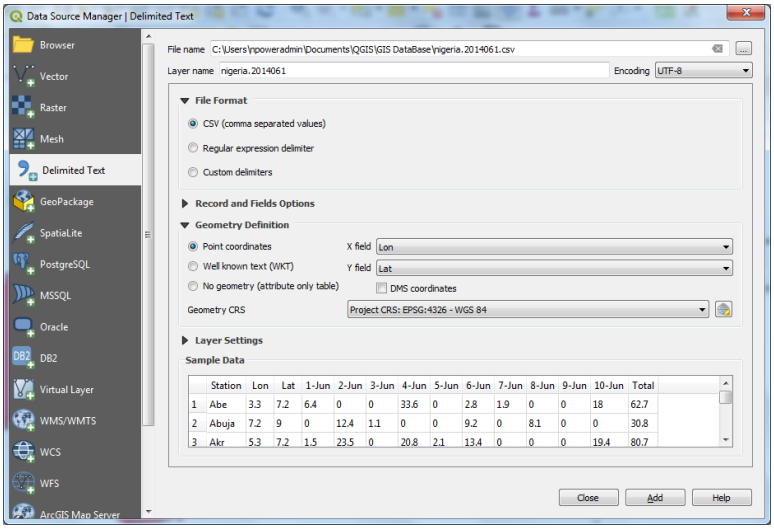
The user may then proceed with the mapping process if he/she wants to produce production-level map.

3. Interpolation



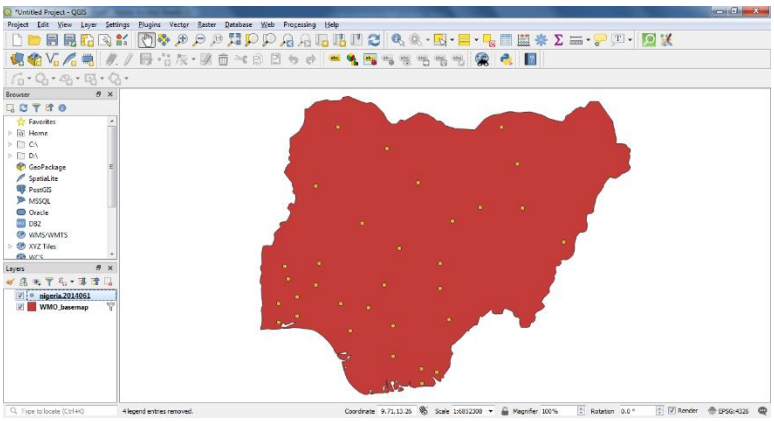
Interpolation of station data is a typical and important operation in weather and climate analysis.

The objective of this section is to interpolate dekadal (10-day period) rainfall totals from stations over Nigeria during early June 2014.



First, import *WMO_basemap,* basemap, and filter over Nigeria. Second, Open Data Source Manager and click *Delimited Text* on the left tab. Under *File name*, browse to *nigeria.2014061.csv*. We note that this data was saved in *Excel* spreadsheet as Comma-Separated Value (CSV) file. In

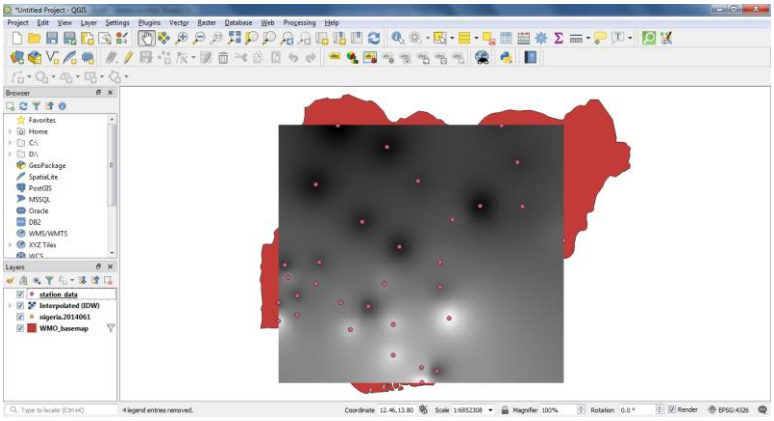
File Format, ensure that *CSV* is selected. In *Geometry Definition*, ensure that *X field* and *Y field* is *Lon* and *Lat*, respectively. Make sure that *Geometry CRS* is set to *EPSG:4326*. Click *Add*.



The location of each station should now appear over Nigeria such as in the following figure.

Next, save the station data as a shapefile. Right-click on *nigeria.2014061*, click on *Export > Save Features As*. Save output file *File name* as *station_data* and as shapefile in your directory. Then click *OK*. The *station_data* layer should now appear as a new layer.

We are going to apply an *Inverse Distance Weighted (IDW)* interpolation to *station_data*. Go to menu *Raster > Analysis > Grid (Inverse Distance to a Power)*. In the *Grid* window, Set *Point layer* to *Station_data*. In *Advanced parameters*, set *Z value from field [optional]* to *Total*. Click *Run*. The interpolated station data should look like the following figure.



Please note that many other interpolation methods are available in QGIS. Most of them are accessible from menu *Processing > Toolbox*.

Now, the user can again perform symbology, clipping, and mapping to produce a production-level map.

For further documentation and training guide on QGIS, please feel free to access the URL:https://qgis.org/en/docs/index.html. Hands-on and practical tutorials are also available at the URL: http://www.qgistutorials.com/en/.