SEST-6577

Geographic Information Systems for Security Studies

Lab 05 (+ Problem Set 5)

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Georeference, vectorize, and compare two maps of polygons

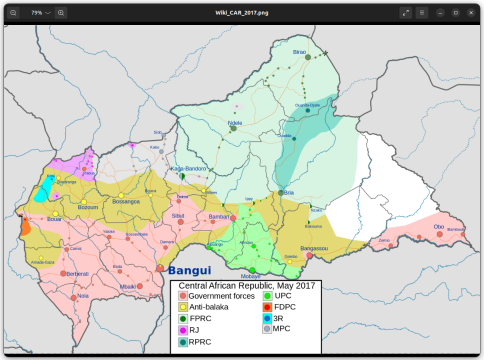


Figure 1: Territorial control in CAR, 2017

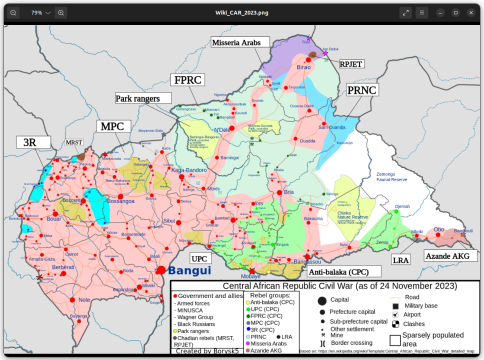
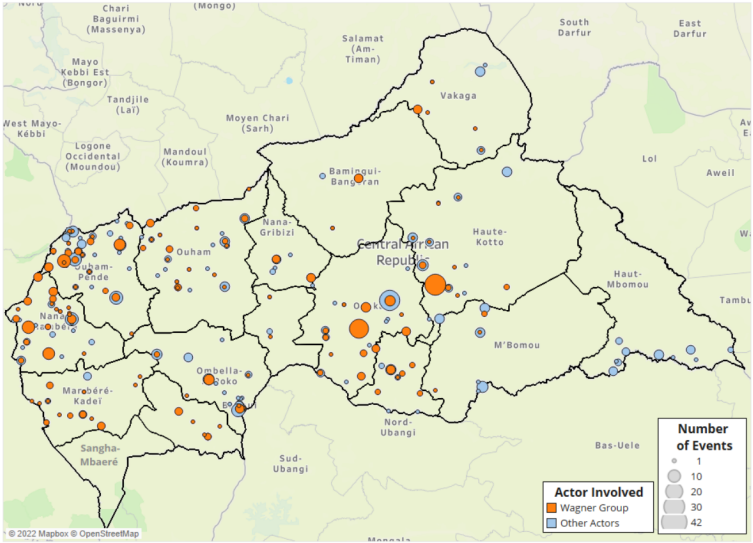


Figure 2: Territorial control in CAR, 2023

Civil war has been raging in the Central African Republic since 2012.
In 2018, Russian mercenaries started actively supporting the government.

After 2021, pro-government forces began a series of offensives to regain control of the country. *Our question*: How successful has this campaign been?



Overview of lab exercise and problem set

1. Lab exercise
   a) Georeference 2017 map (new method)
   b) Re-use GCPs to georeference 2023 map
   c) Create new polygon layer for government control
2. Problem set
   a) Map comparing government control in 2023 to 2017

We will use image tracing to vectorize areas of control on a crowd-sourced map

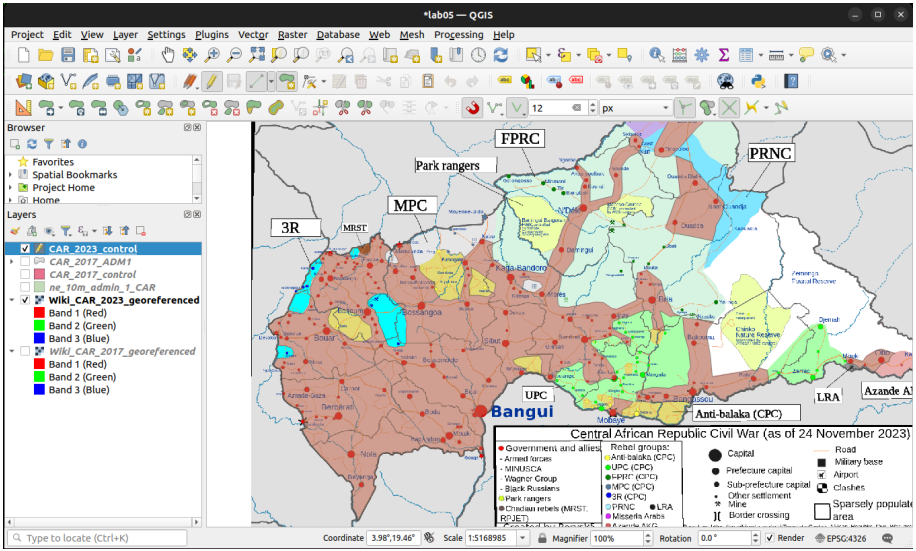


Figure 3: Vectorized polygons

. . . to calculate percent of each province controlled by the CAR government in 2023

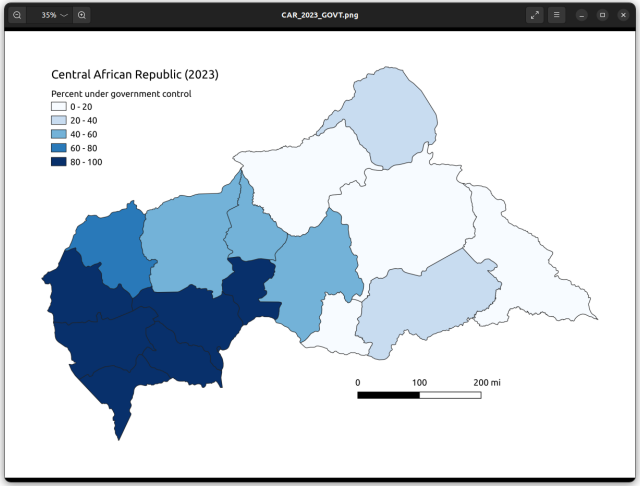


Figure 4: CAR government control, 2023

. . . and 2017

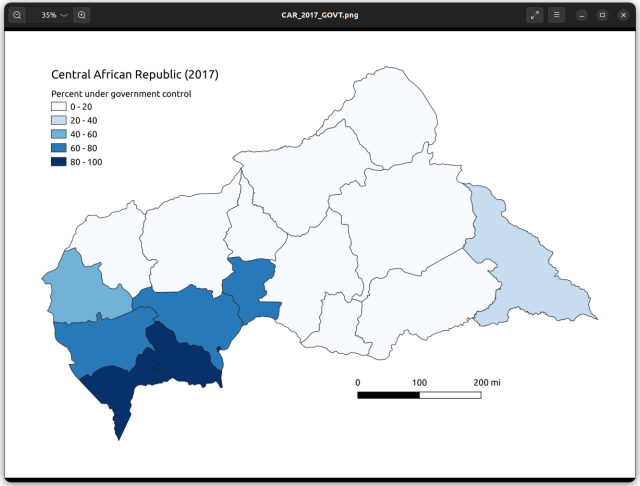


Figure 5: CAR government control, 2017

You will make this map for your **problem set**

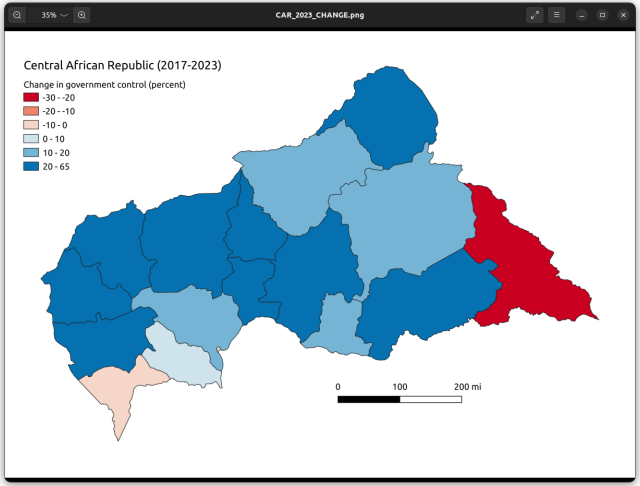


Figure 6: Save as `CAR_2023_CHANGE.png`

We have two **sources of data**:

Category	Type	Format	Data source
Territorial control in CAR	Raster (non-spatial)	`.png`	`Wikipedia`
CAR province borders	Vector (polygons)	`.geojson`	`naturalearthdata.com`

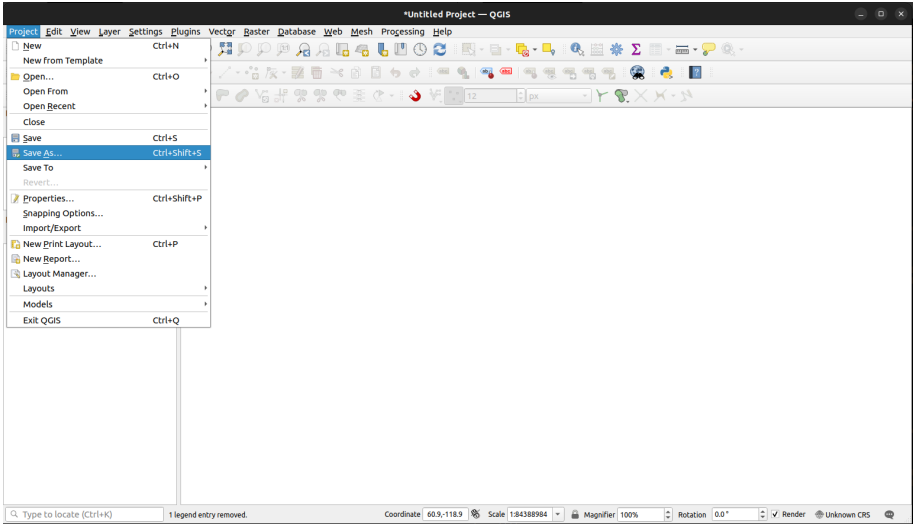
These are all in the `Lab05PS05.zip` file posted on Canvas.

Let's open QGIS...

QGIS

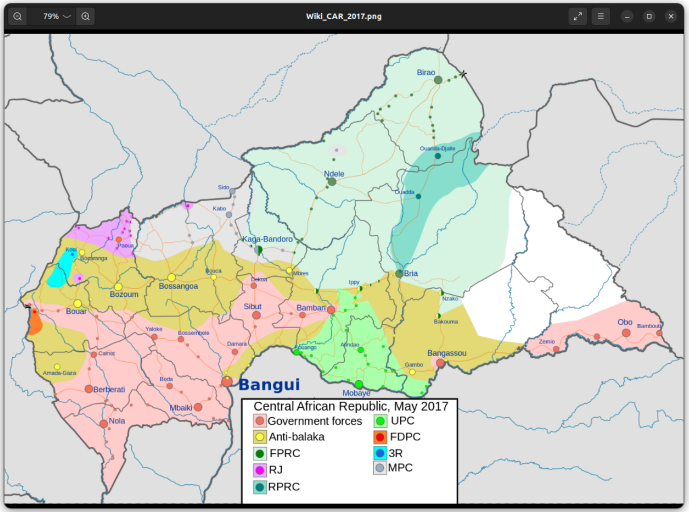
Always save your progress!

Go to `Project` → `Save As...`

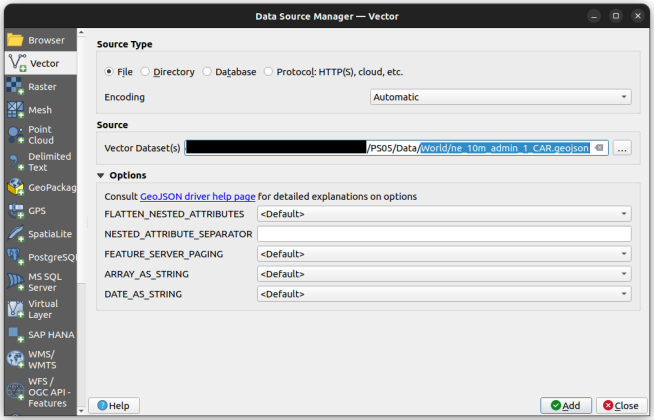


Georeferencing

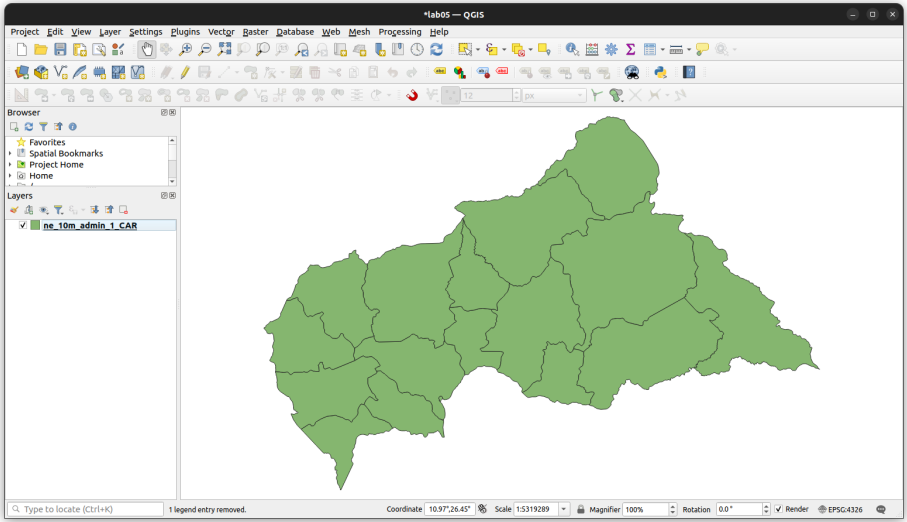
Unlike the last lab, the map we're georeferencing here has no graticule lines.
To georeference it, we'll need to use a basemap of CAR as reference.



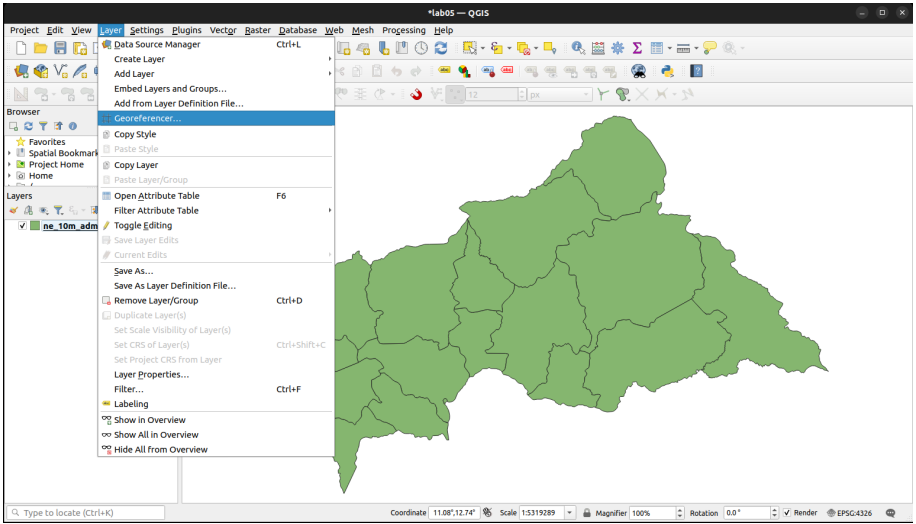
Let's *open the basemap* we'll be using for georeferencing.
Go to `Layer` → `Add Layer` → `Add Vector Layer...`.
Navigate to `ne_10m_admin_1_CAR.geojson` in `Data/World`



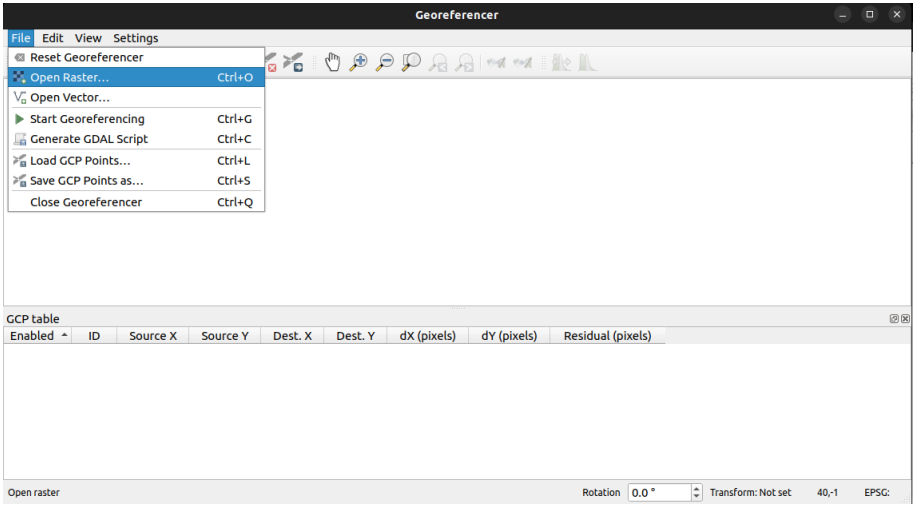
This will load province-level (admin-1) boundaries for CAR



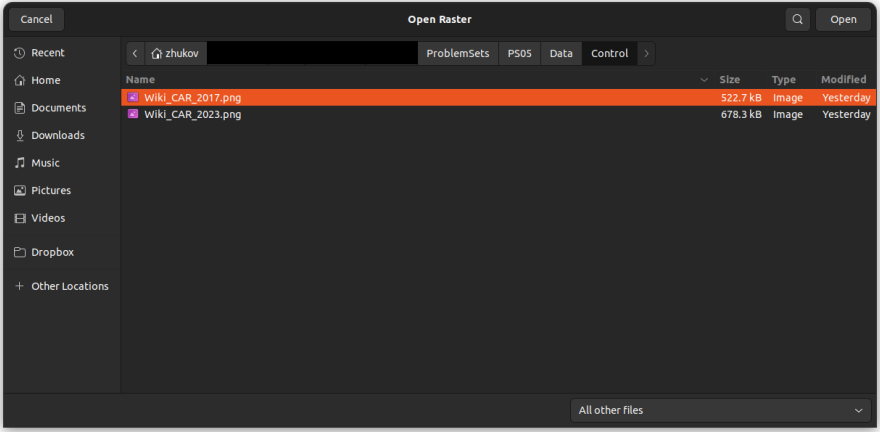
To *open the georeferencer*, click on `Layer` → `Georeferencer`



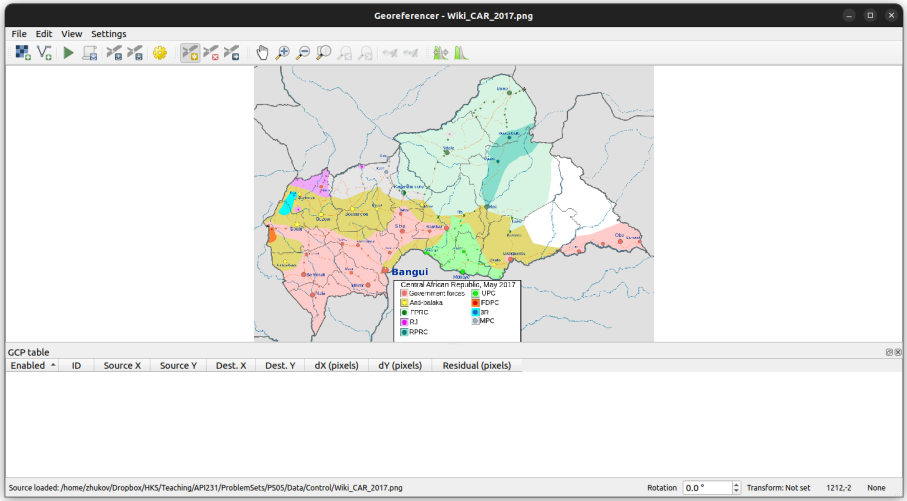
This will open an empty Georeferencer window.
To open our PNG image, go to `File` → `Open Raster`



Navigate to the `Wiki_CAR_2017.png` image in `Data/Control`. Click `Open`



The map image will appear in the Georeferencer's top pane.

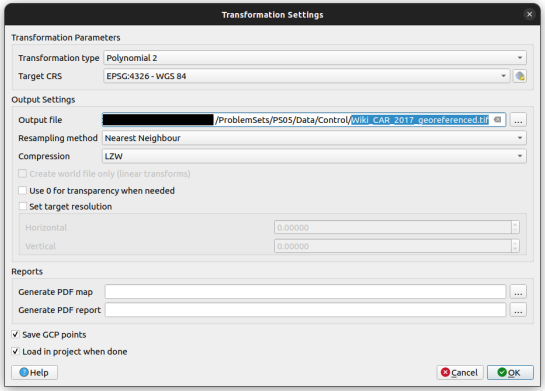


Go to Settings menu → Transformation settings

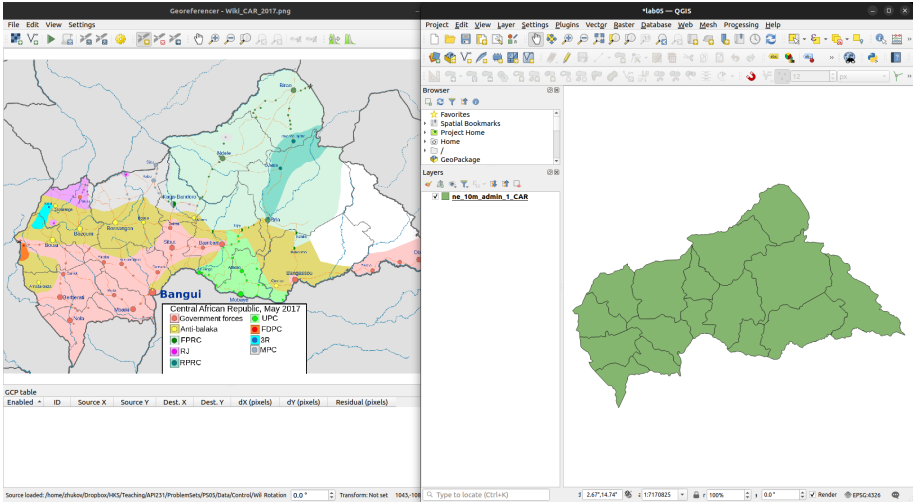
Set

- Transformation type = Polynomial 2
- Target CRS = EPSG:4326 - WGS 84
- Output file = select a folder, name the output file Wiki_CAR_2017_georeferenced.tif
- Resampling method = Nearest neighbor
- Compression = LZW
- ✓ Save GCP points
- ✓ Load in QGIS when done

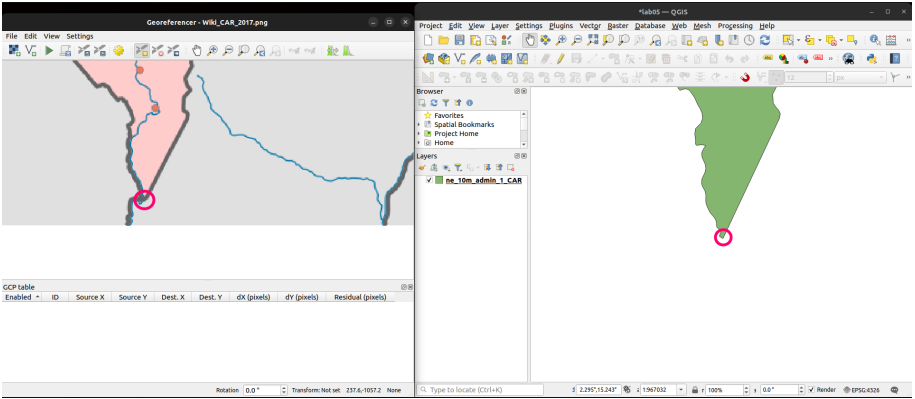
Click OK



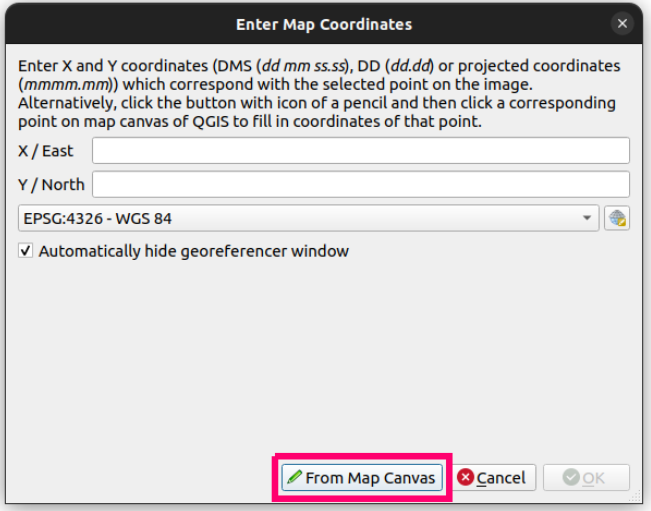
Try to set up the interface so that the Georeferencer window (left) and Project window (right) are both visible, or at least accessible, on your screen



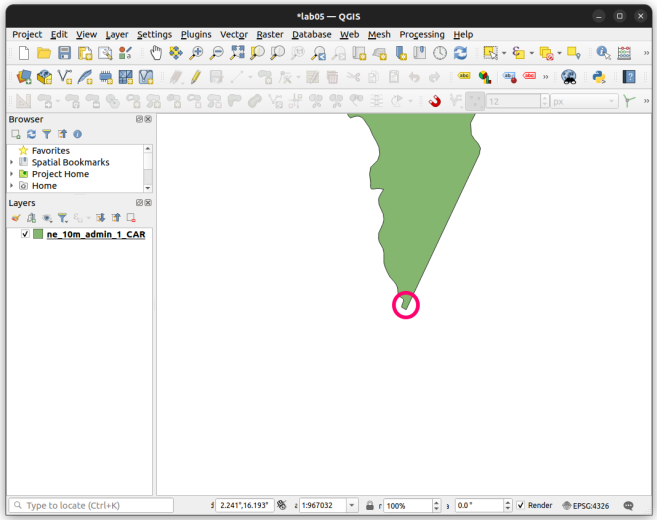
Let's place our first ground control point (GCP) at the southern-most tip of CAR. Click the point marked in red in the Georeferencer (left)



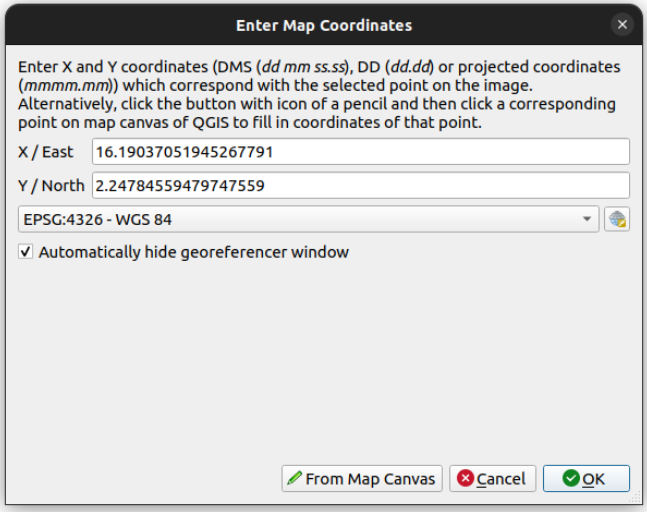
Rather than entering the x and y coordinates manually, click `From Map Canvas`



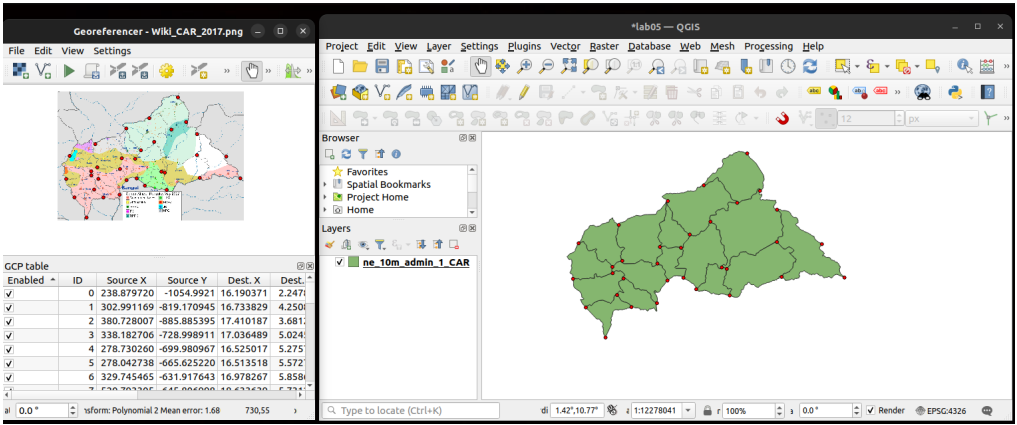
The view will switch to the Project window. Click the corresponding point on the administrative boundaries layer



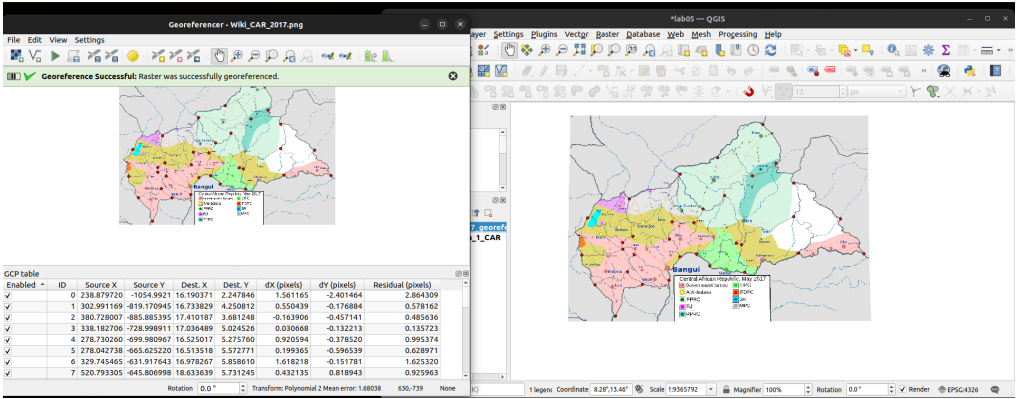
The coordinates you selected will automatically appear in the `Enter Map Coordinates` window. Click `OK`



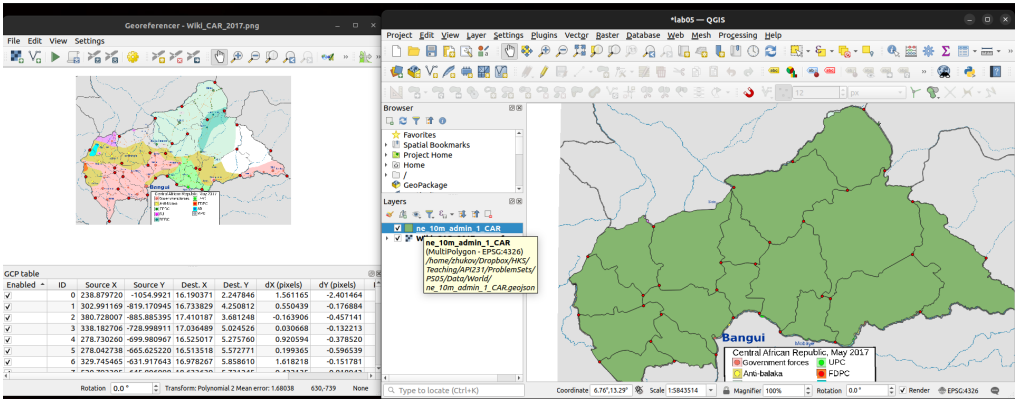
Repeat this process for every three-way provincial border intersection, and as many recognizable outer boundary points as possible, until the GCPs have broad coverage (there are 32 GCPs in the example shown here)



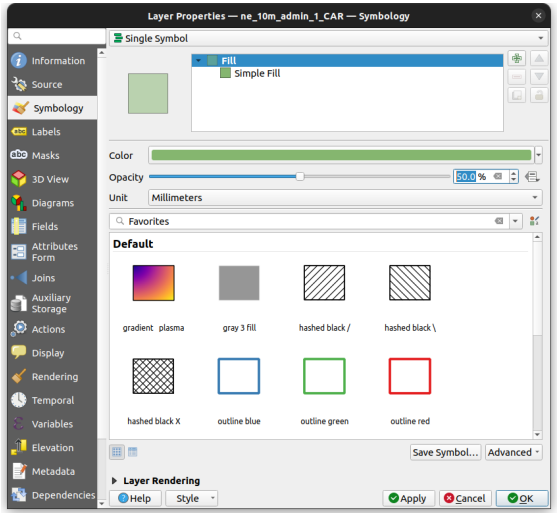
Once you have a critical mass of GCPs, click on `Start georeferencing` (▶) button. If the process is successful, you will see a notification at the top



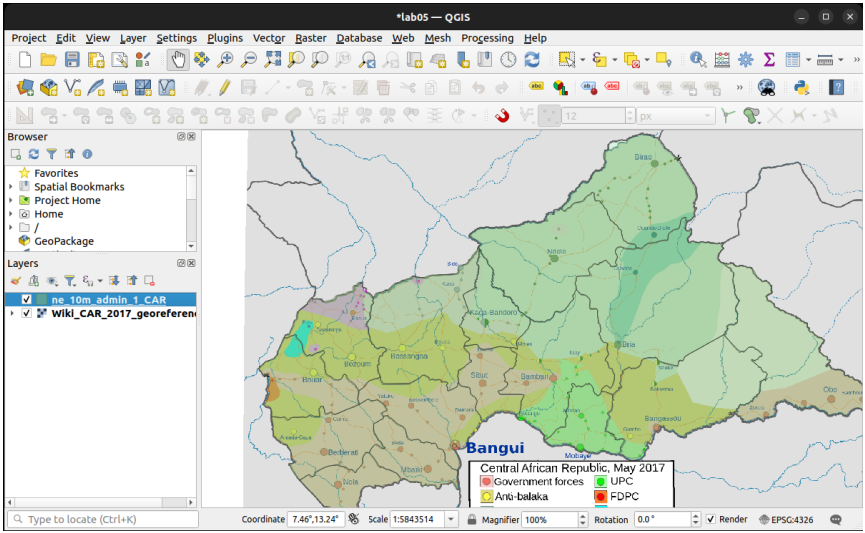
Before closing the Georeferencer window, let's *check the quality of fit*.
Back in the Project window, move the boundaries above the georeferenced raster in the Layers menu



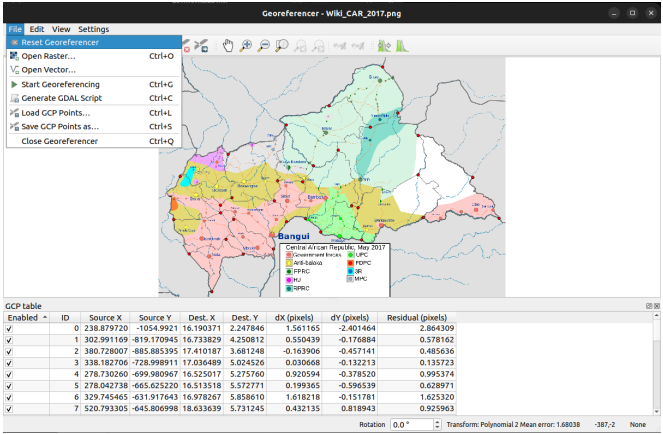
Let's make the countries layer semi-transparent. Double-click on the layer, go to `Properties` → `Symbology`. Set `Opacity` = 50



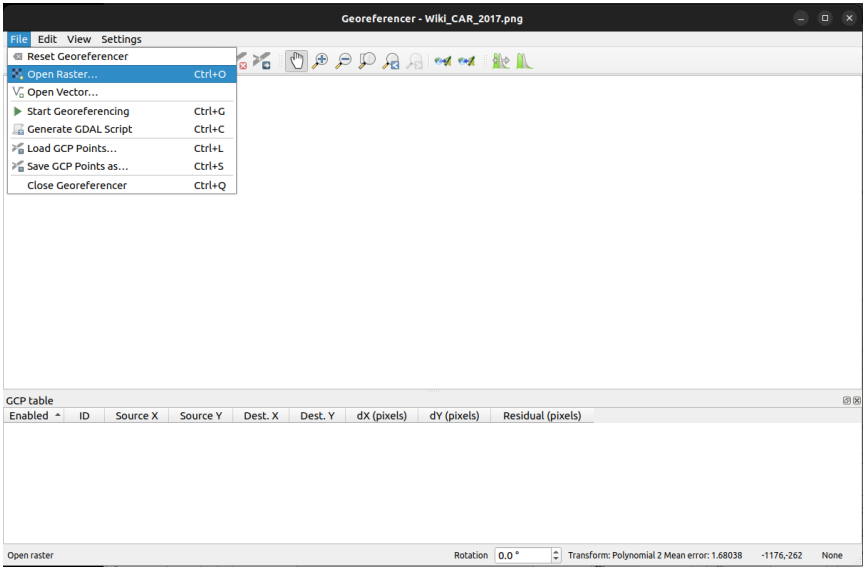
Check the quality of the fit. If you see any problematic mis-alignments, go back to Georeferencer, add more GCPs and run it again. The fit here seems ok...



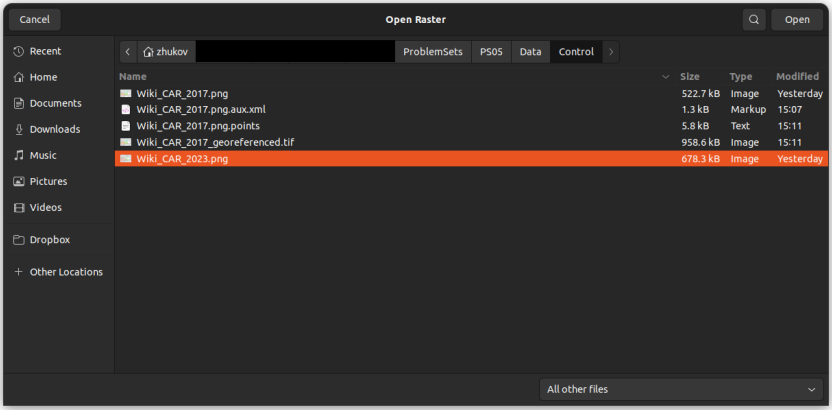
Let's now georeference the second map. To open a new Georeferencer window, go to `File` → `Reset Georeferencer` (or just open and re-launch the window)



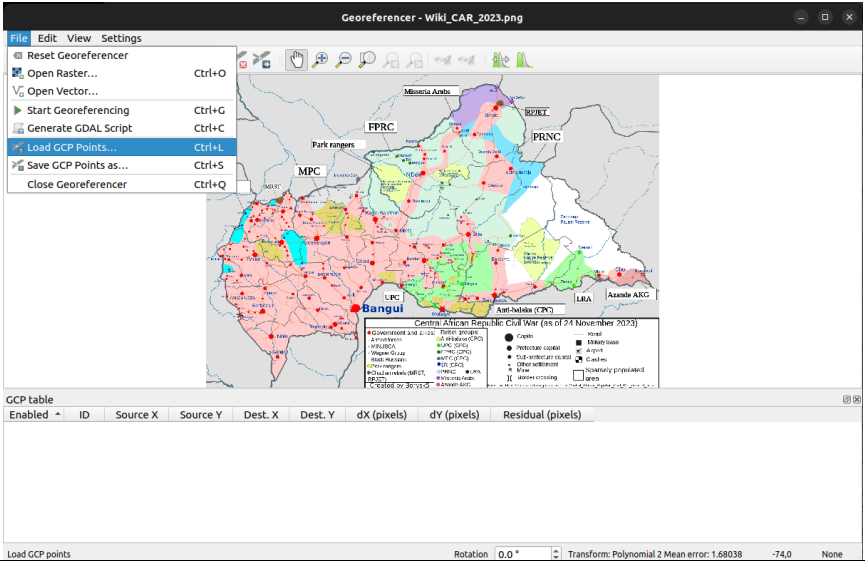
To open the other PNG image, go to `File` → `Open Raster`



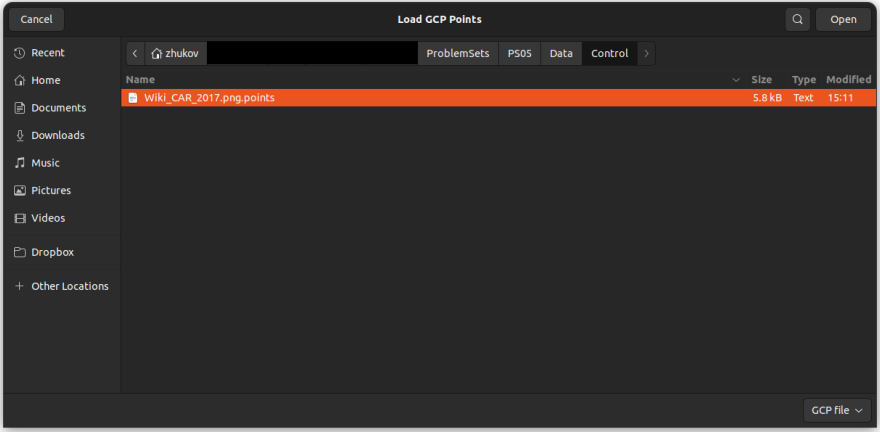
Navigate to the `Wiki_CAR_2023.png` image in `Data/Control`. Click `Open`



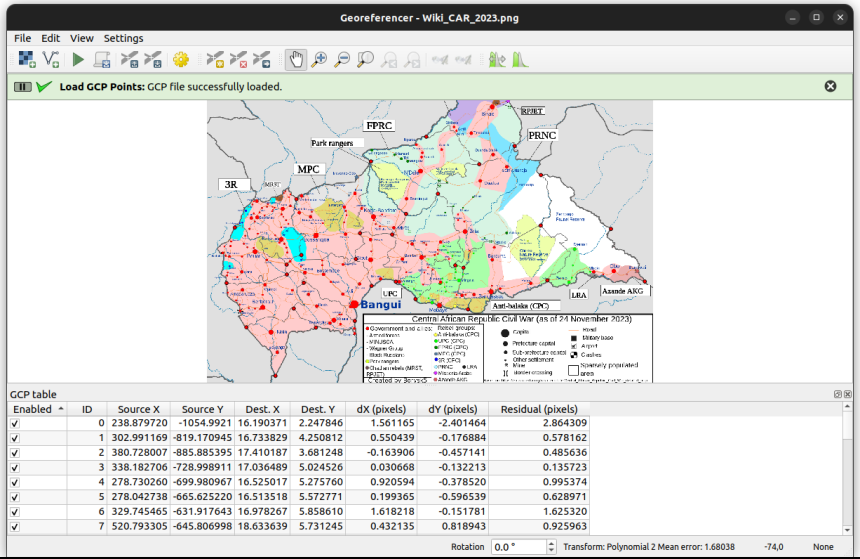
Because the dimensions and extent of this map seem identical to the previous one, we will try to *reuse the same GCPs*. Go to `File` menu → `Load GCP Points...`



Navigate to the file `Wiki_CAR_2017.png.points` in `Data/Control`. Click `Open`



If the import was successful, you should see the same GCPs reappear in the Georeferencer window

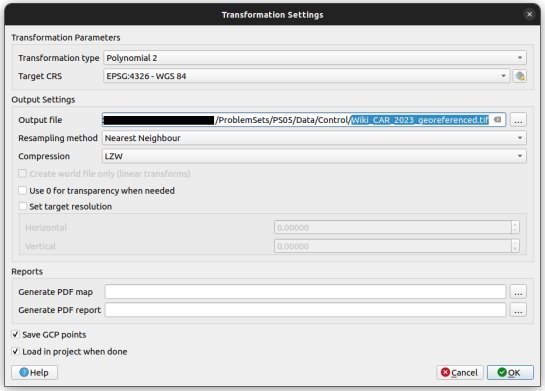


Go to Settings menu → Transformation settings

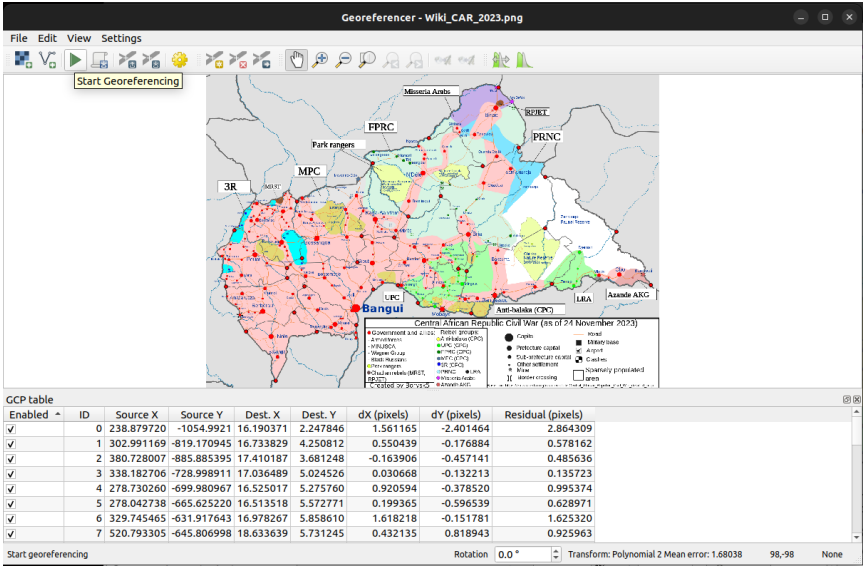
Set

- Transformation type = Polynomial 2
- Target CRS = EPSG:4326 - WGS 84
- Output file = select a folder, name the output file Wiki_CAR_2023_georeferenced.tif
- Resampling method = Nearest neighbor
- Compression = LZW
- ✓ Save GCP points
- ✓ Load in QGIS when done

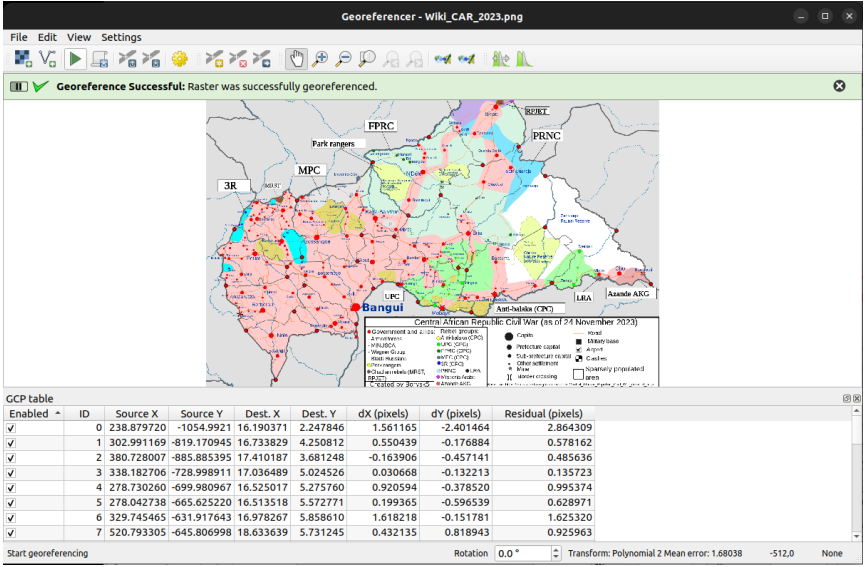
Click OK



If everything looks fine, click on `Start georeferencing` (▶) button

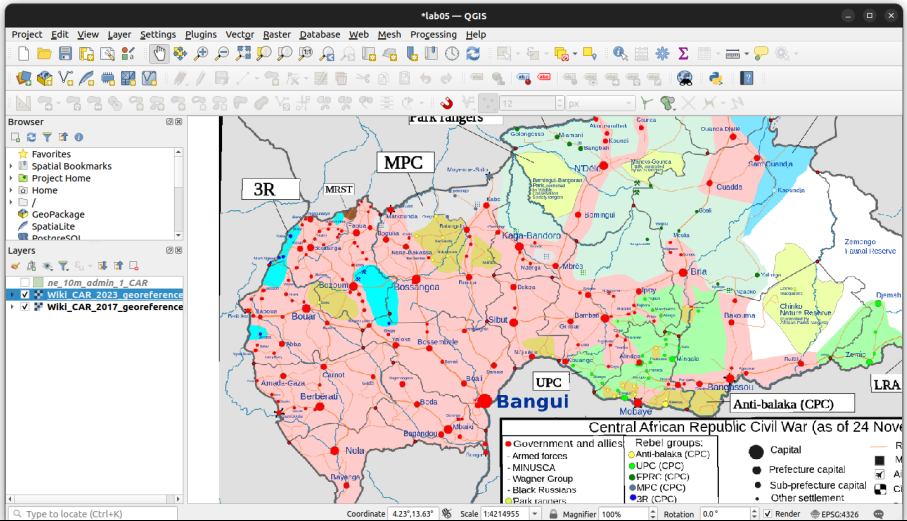


You will see a notification at the top once the georeferencing is complete



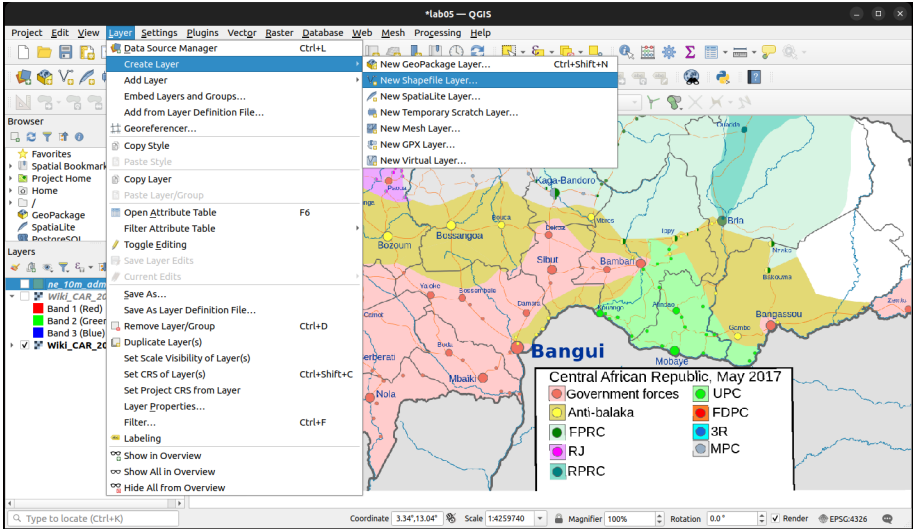
Back in the Project window, both georeferenced rasters should be in the Layers menu.

Now let's vectorize the raster (create polygons of government control)



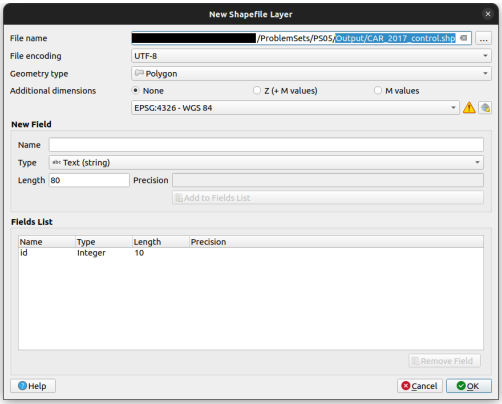
Vectorization

Go to Layer → Create Layer → Create New Shapefile Layer...

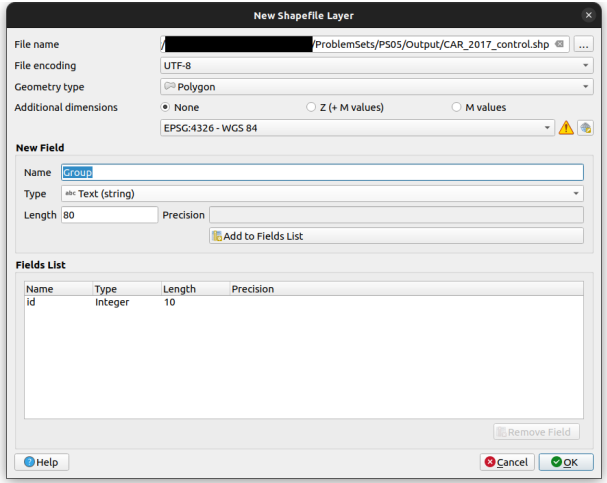


Set

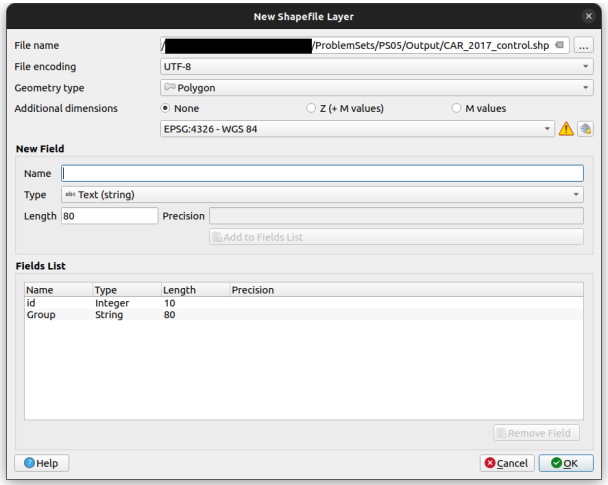
- `File name` = `CAR_2017_control.shp` in `Output` folder
- `Geography type` = `Polygon`
- select `EPSG:4326 - WGS 84` for the CRS



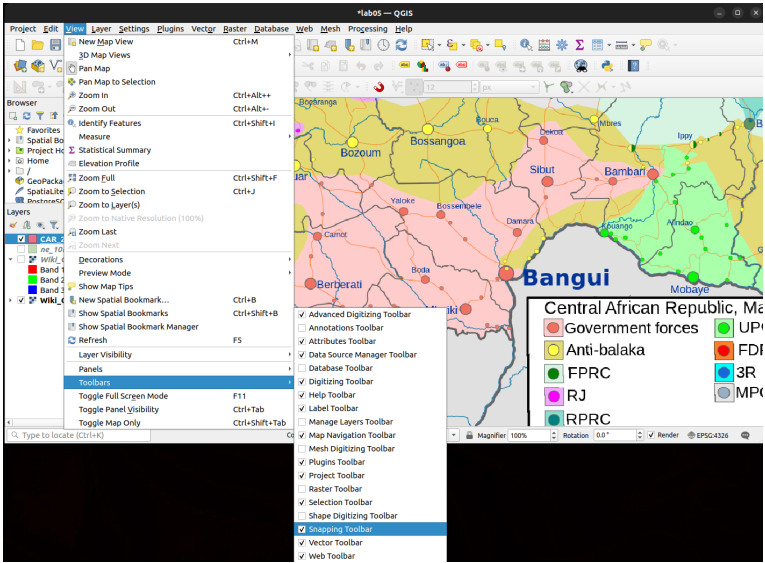
Let's add a new field to the attribute table:
`Name` = `Group`, `Type` = `Text`. Click `Add to Fields List`



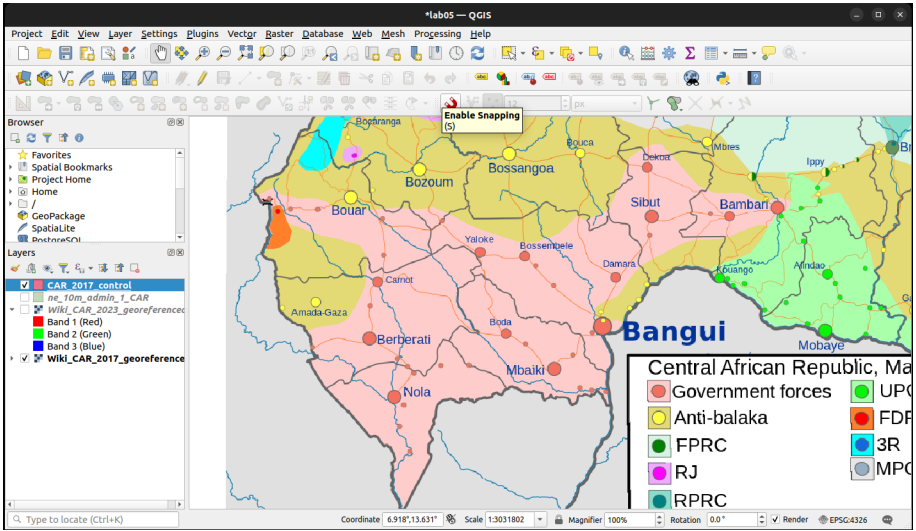
Click OK


New Shapefile Layer
File name
[redacted]/ProblemSets/PS05/Output/CAR_2017_control.shp
File encoding
UTF-8
Geometry type
Polygon
Additional dimensions
None
Z (+ M values)
M values
EPSG:4326 - WGS 84
New Field
Name
Type
Text (string)
Length
80
Precision
Add to Fields List
Fields List
Name
Type
Length
Precision
id
Integer
10
Group
String
80
Remove Field
Help
Cancel
OK

Let's *enable snapping*. `View` menu → `Toolbars` → `Snapping Toolbar`

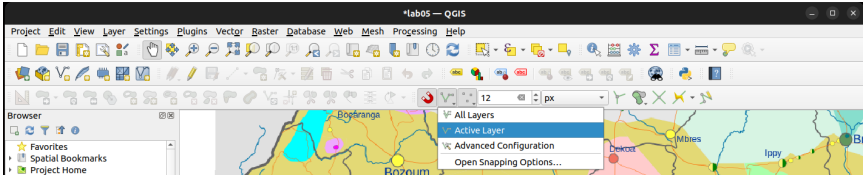


Click on the "Magnet button in the toolbar

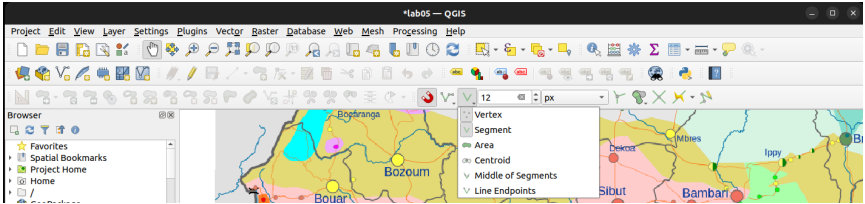


For the other Snapping toolbar buttons, set the following parameters:

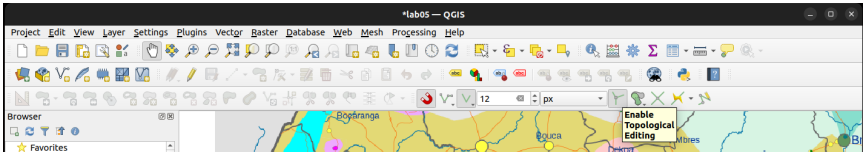
- ✓ `Active Layer`



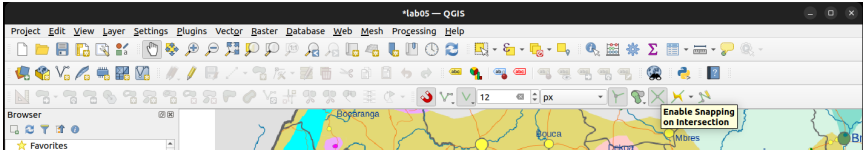
- ✓ `Vertex`
- ✓ `Segment`



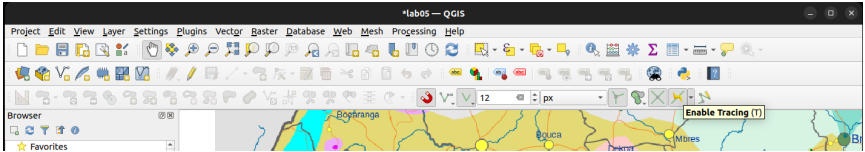
- ✓ Enable Topological Editing



- ✓ Enable Snapping on Intersection

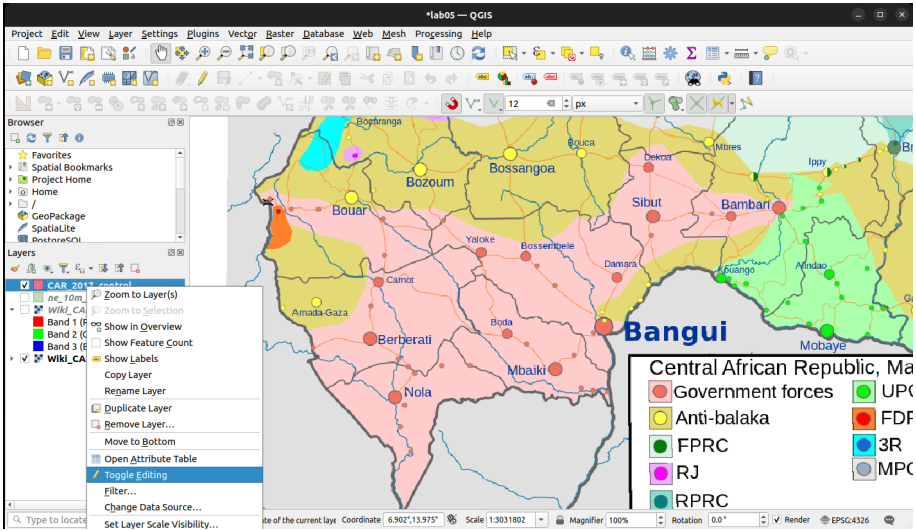


- ✓ Enable Tracing

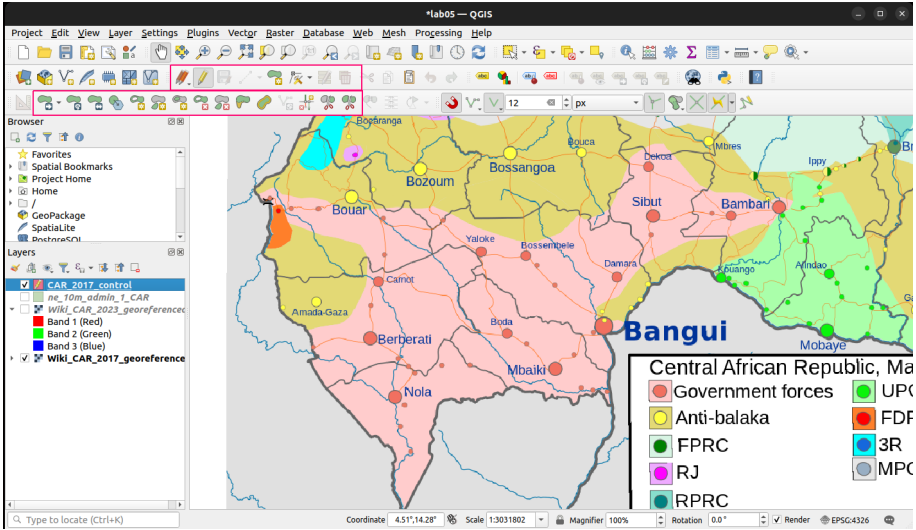


Let's go into *editing mode*.

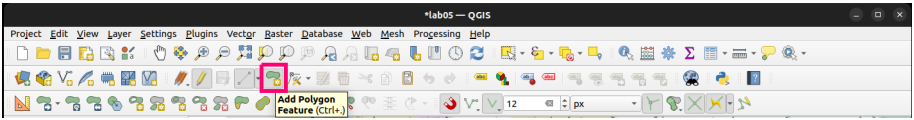
`Right-click` on `CAR_2017_control` in Layer menu → `Toggle Editing`



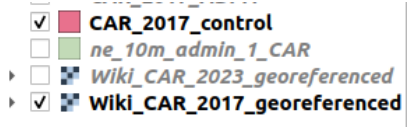
This will activate the Editing Toolbar



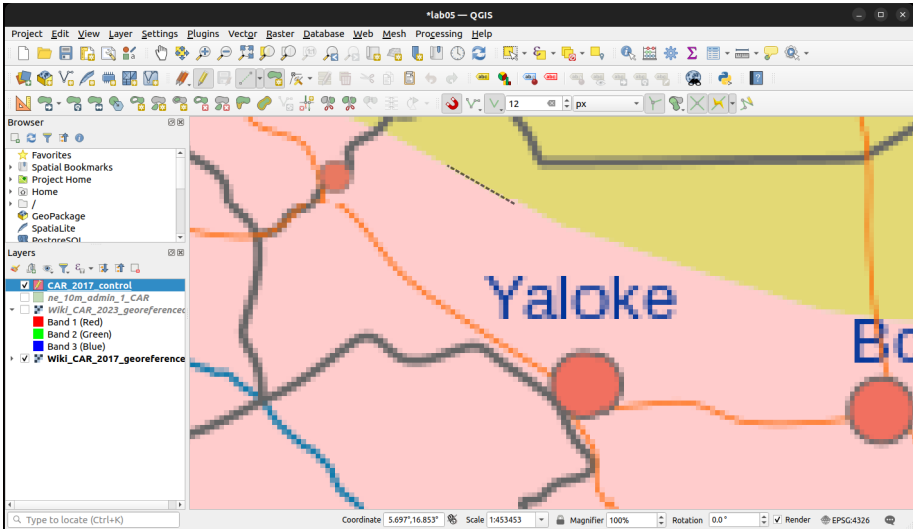
Click on the `Add Polygon Feature` icon (looks like a "blob" and a star, just to the right of the pencil, on the Editing Toolbar)



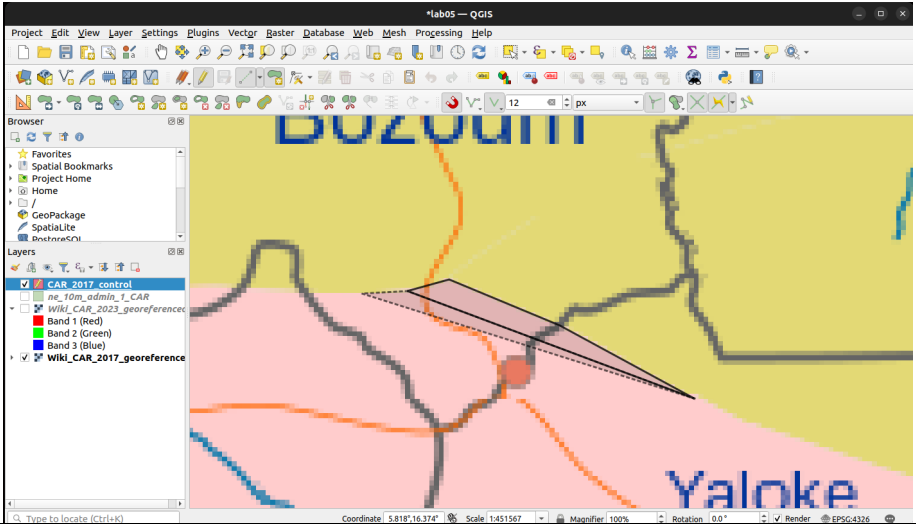
Tip: you may also want to *hide the inactive layers* while you vectorize.
For example, you don't need (for now) the administrative boundary basemap (`ne_10m_admin_1_CAR`) or the 2023 raster (`Wiki_CAR_2023_georeferenced`). In the Layer menu, uncheck the boxes next to everything other than `CAR_2017_control` and `Wiki_CAR_2017_georeferenced`



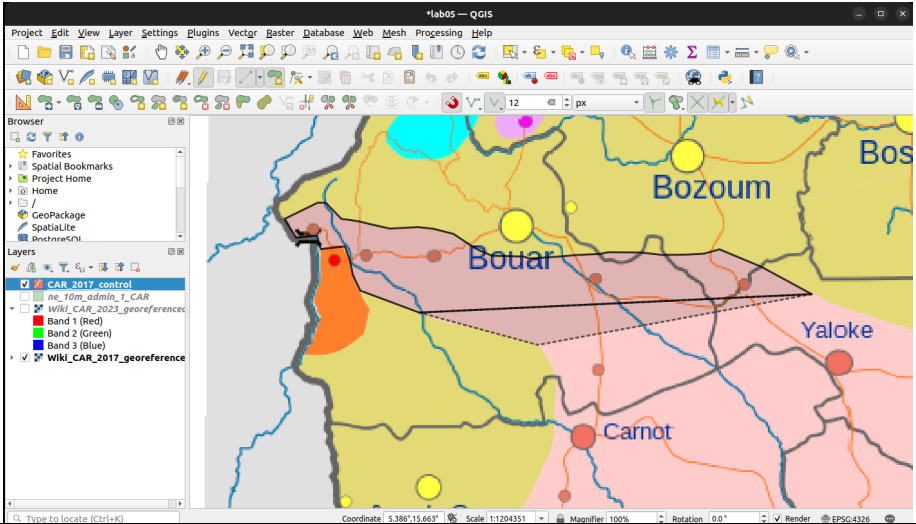
Make sure `CAR_2017_control` is highlighted in the Layer menu. Start tracing the pink area (representing government control) by left-clicking on its boundary



As with polylines, each feature you create is a set of inter-connected line segments. The difference with polygons is that they are “closed sets” of vertices, meaning that the end point will (eventually) be at the same location as the start point



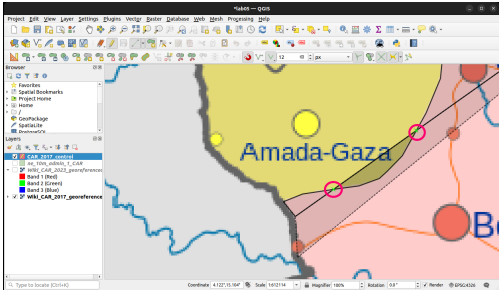
Each left-click ends one straight-line segment and begins another (make sure you add enough segments to capture the curvature of the border). As you keep adding vertices, the polygon will gradually take shape

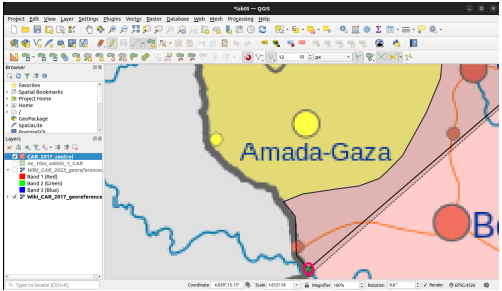


Every once in a while, you'll see green x's appear while creating a new feature. This typically means one of two things:

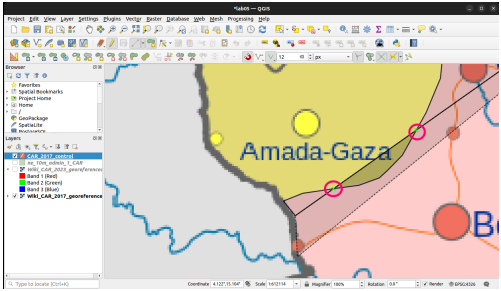
1. The polygon has a self-intersection
2. You placed multiple vertices in the same location (by clicking twice)

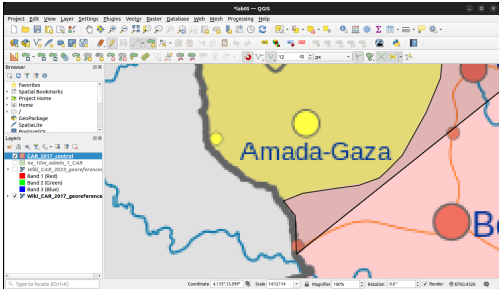
These are both considered geometry errors, and should be avoided.



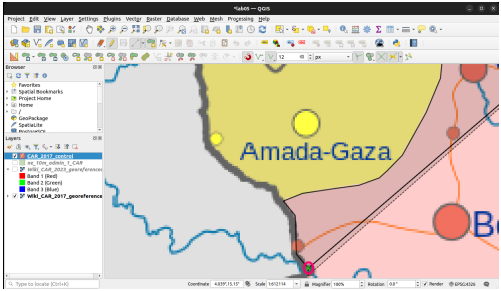


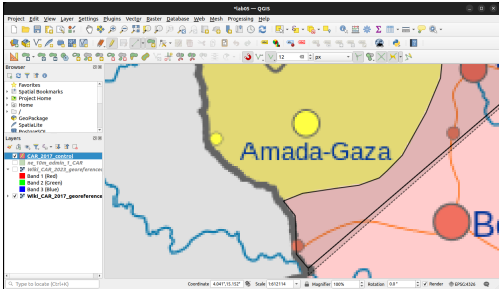
Sometimes (but not always), *self-intersections* "untangle" themselves as you add more vertices and refine the shape of the polygon:



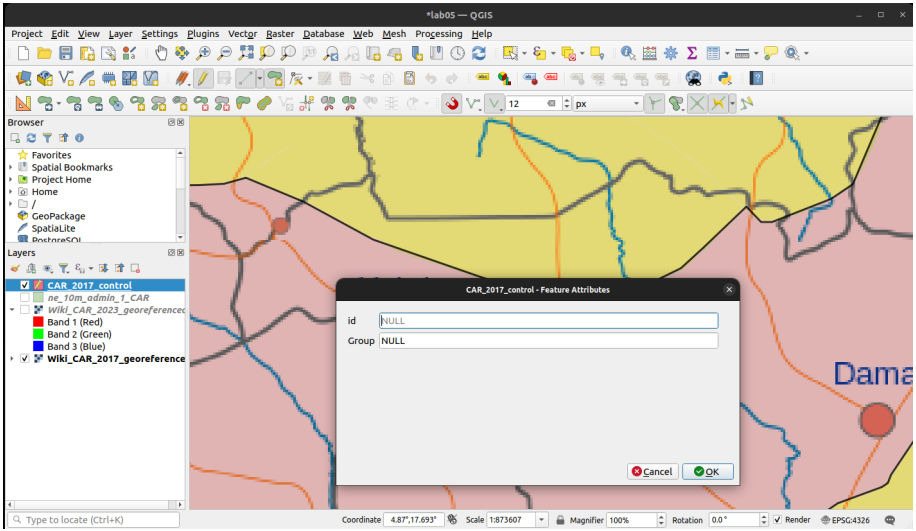


With *duplicate vertices*, you'll need to go back to get rid of the double point (by clicking delete/backspace)

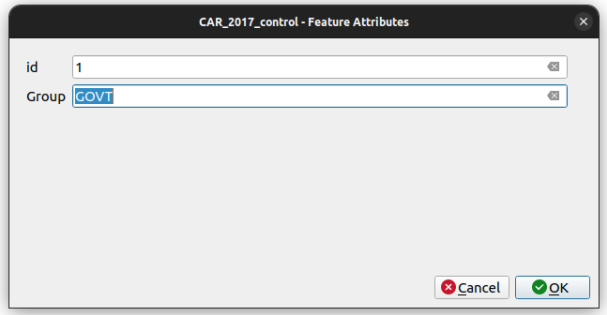




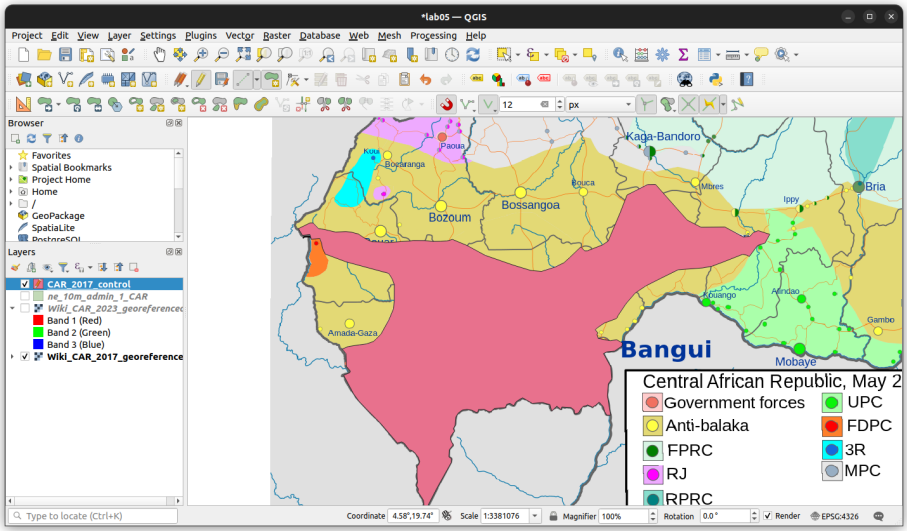
As you approach the end of the loop, right-click to add the feature. You'll be prompted to fill out the field information



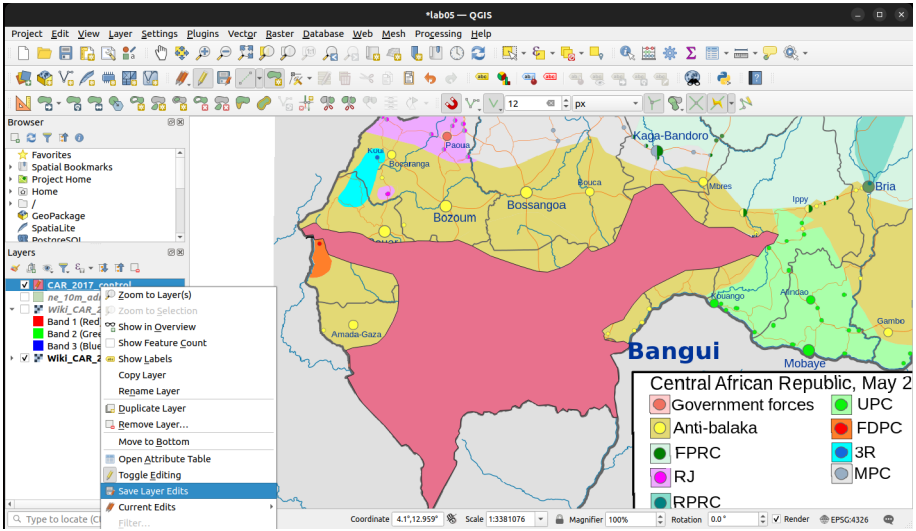
For the `id` field, enter the number of the polygon (e.g. "1" if it's the first one you created). For `Group`, enter `GOVT`.



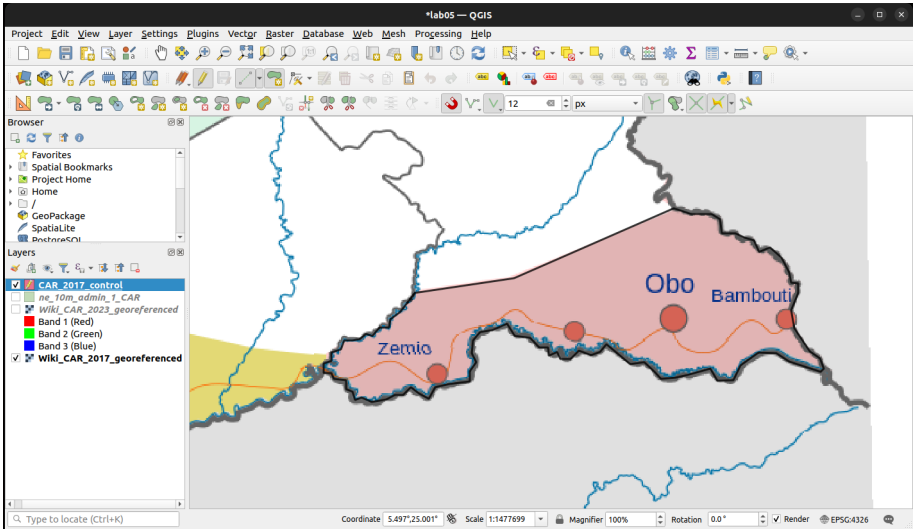
The new feature should appear on the map



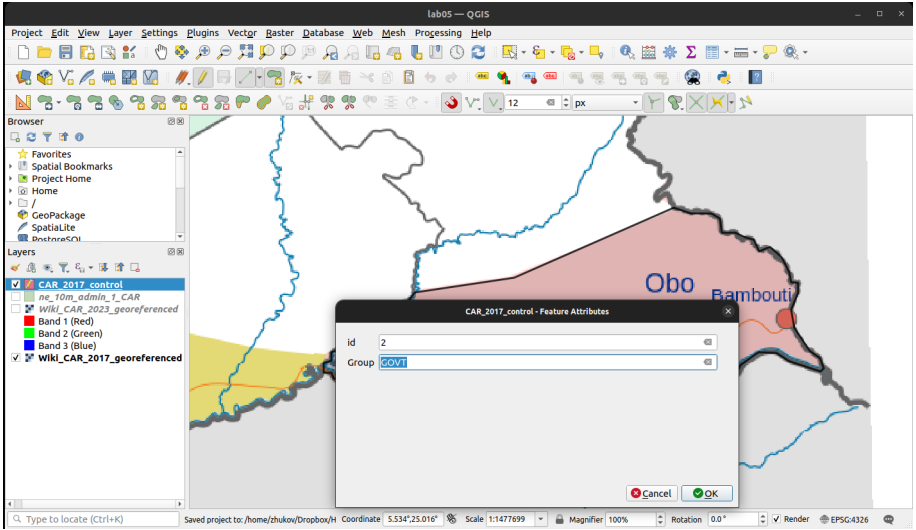
Save your progress by right-clicking on `CAR_2017_control` in the Layer menu, and selecting `Save Layer Edits`.



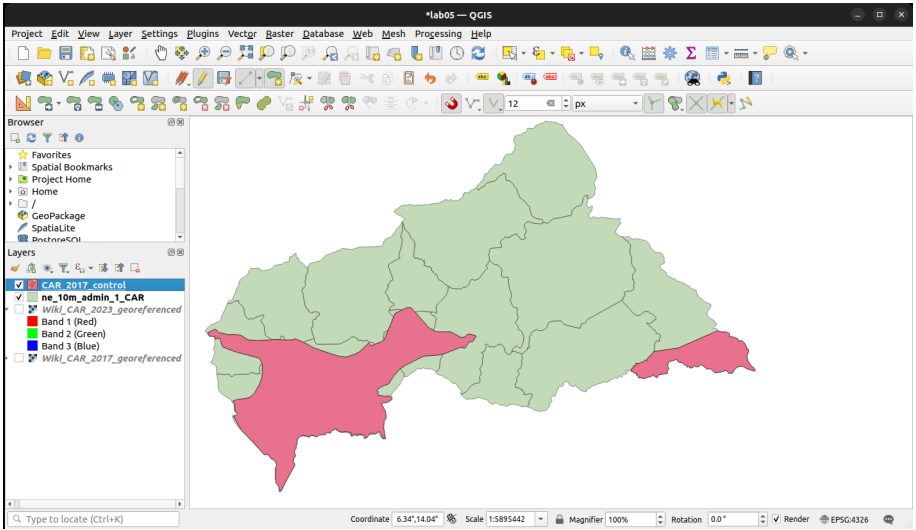
Repeat the same steps for the other government-controlled area in the east of the country (there should be two such polygons total in the 2017 map)



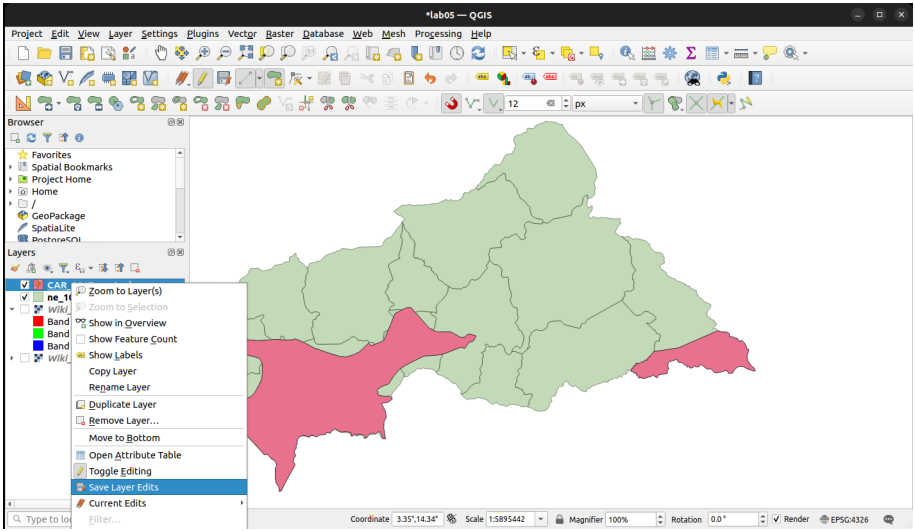
The attributes here should be `id` = 2 and `Group` = `GOVT`



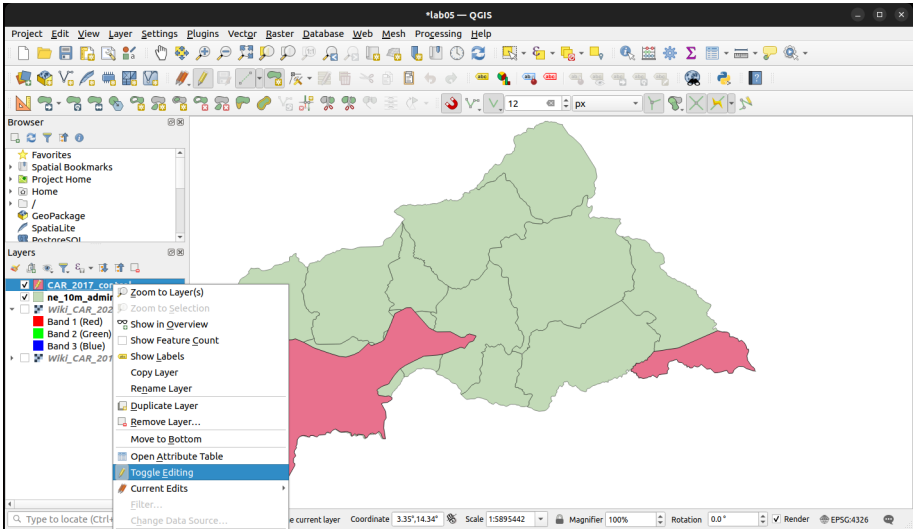
Here's how the vectorized polygons should look when you're done (reactivating the `ne_10m_admin_1_CAR` layer for context)



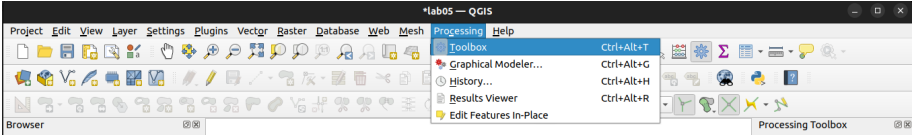
Save your progress (again) by right-clicking on `CAR_2017_control` in the Layer menu, and selecting `Save Layer Edits`.



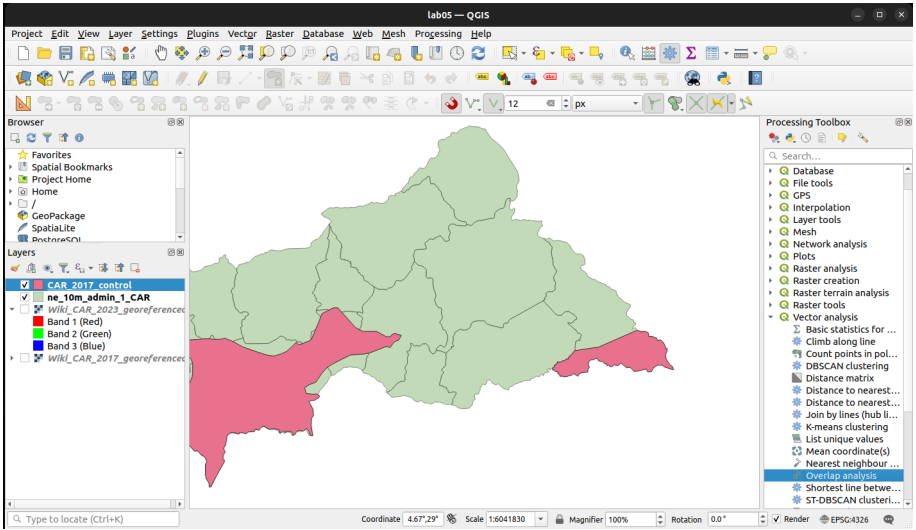
Turn off editing mode by right-clicking on `CAR_2017_control` in the Layer menu, and de-selecting `Toggle Editing`.



Let's *calculate the percent of each province under government control*.
Open the *Processing Toolbox* (`Geoprocessing` menu → `Toolbox`)

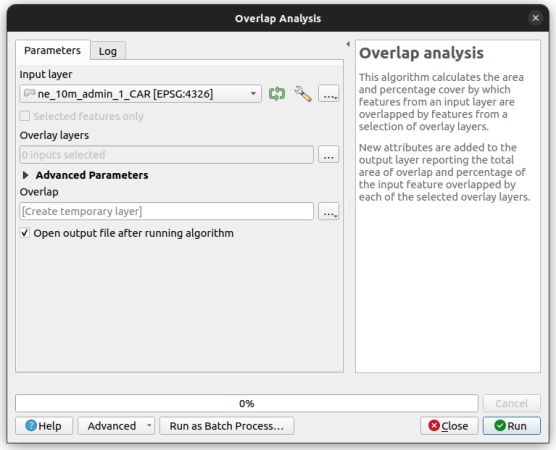


In the Processing Toolbox in the right, `double-click` on `Overlap analysis` in the `Vector analysis` sub-menu



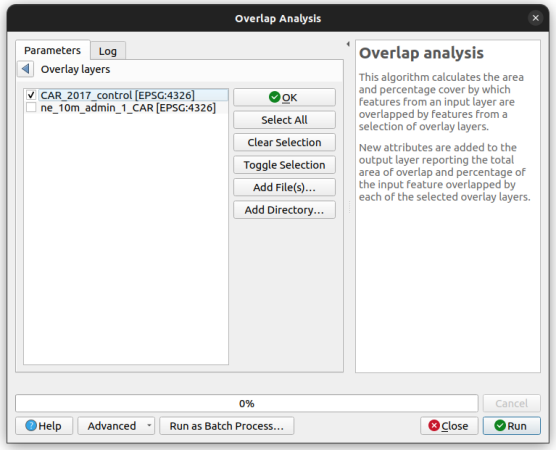
In the Overlap Analysis window, set

- `Input layer` = `ne_10m_admin_1_CAR`



Set

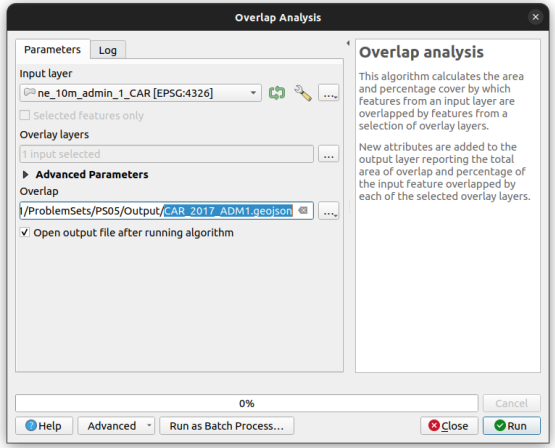
- `Overlay layers` = `CAR_2017_control`



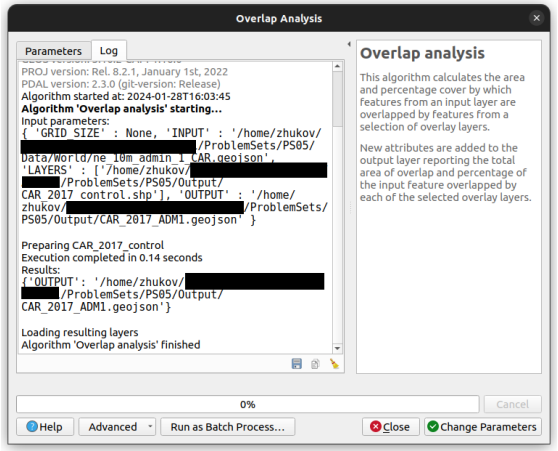
Set

- `Overlap` (file output) = `CAR_2017_ADM1.geojson` in `Output` folder.

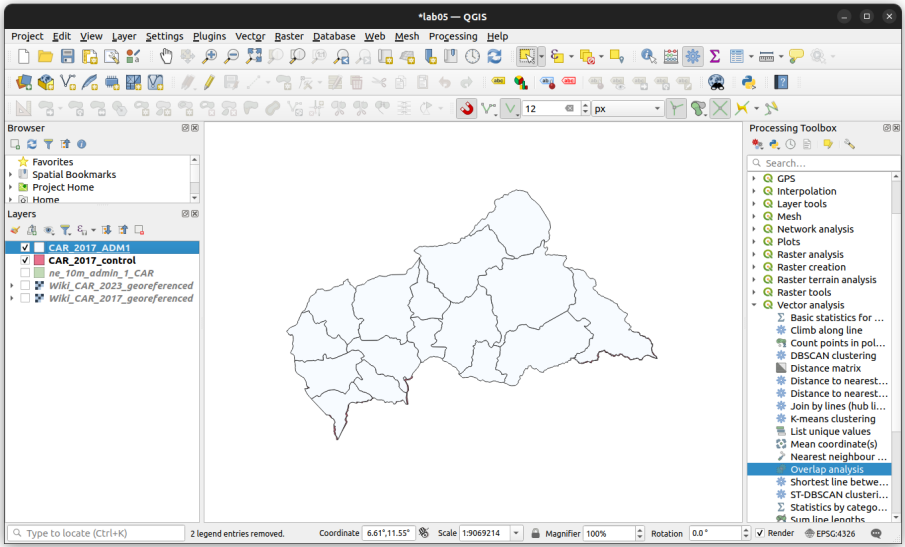
Click `Run`



Check the log to make sure there were no errors

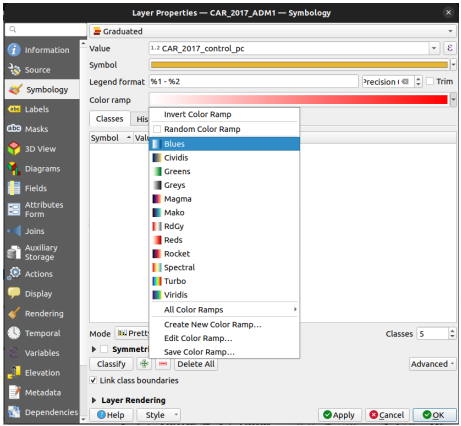


A new layer `CAR_2017_ADM1` should appear in the map and Layer menu. `Double-click` on it to open up its Properties



Set

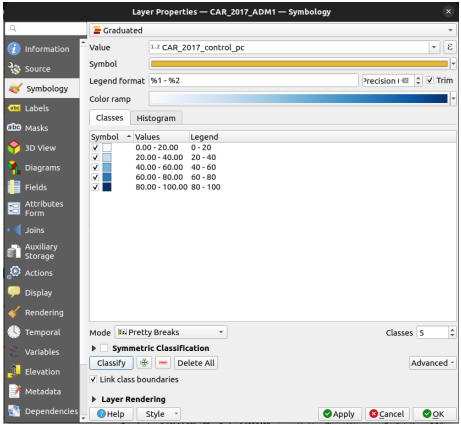
- `Symbology type` = `Graduated`
- `Value` = `CAR_2017_control_pc`
- `Color ramp` = `Blues`



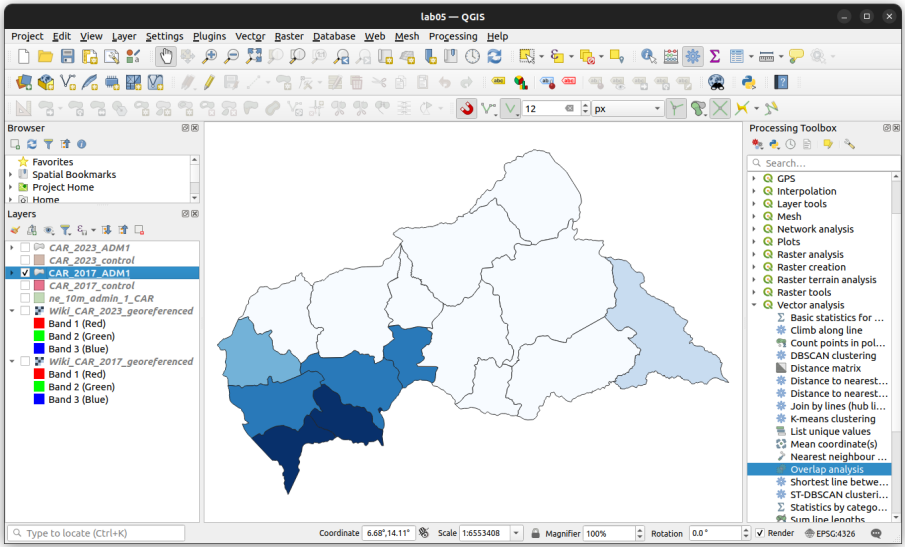
Set

- Mode = Pretty Breaks
- Click Classify

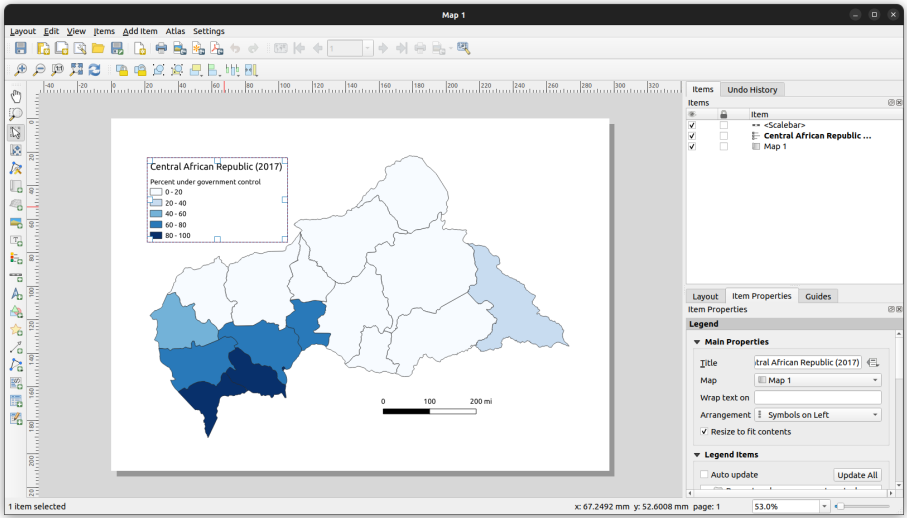
Click OK



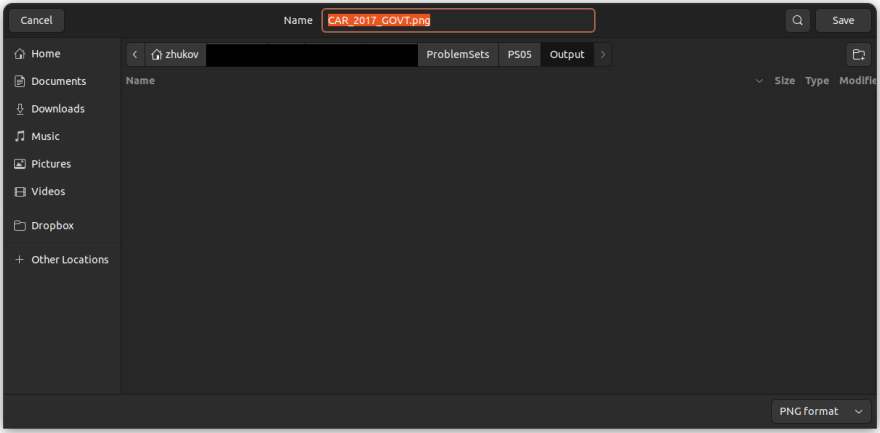
The province polygons should now be colored according to percent of territory controlled by the government



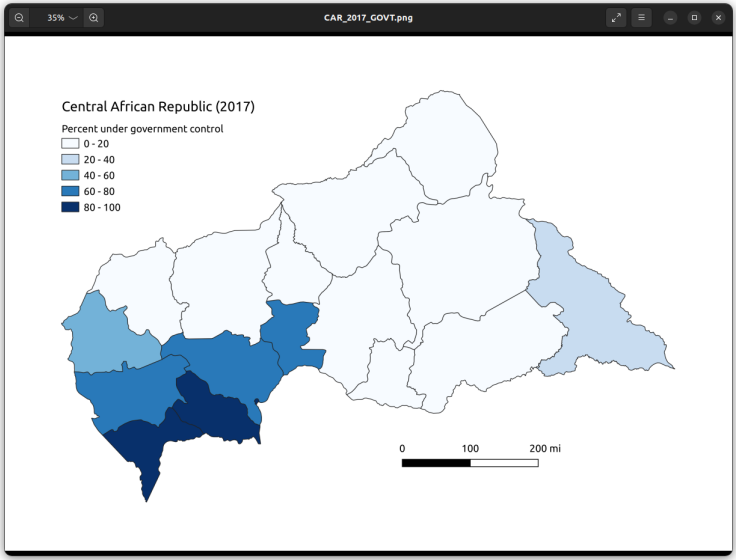
Make a `New Print Layout`, fixing the legend as always and adding a scale bar



Export the image as `CAR_2017_GOVT.png`



The output file should look something like this



Problem Set 5

Your assignment:

- create a map of change in government control, 2017-2023
- vectorize polygons in `Wiki_CAR_2023_georeferenced`
- do overlap analysis
- create new field: difference between 2023 and 2017
- export the map as an image, showing:
  - provinces colored by 2023-2017 difference
  - legend and scale bar
- name the file `CAR_2023_CHANGE.png`
- upload to Canvas (by Wed)

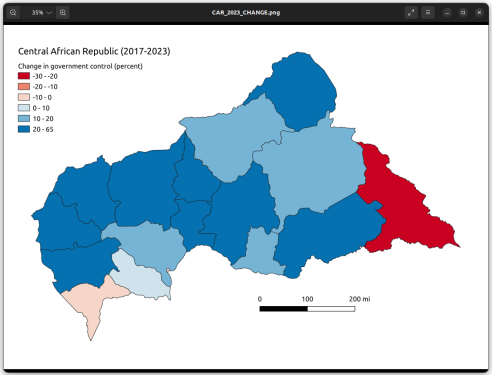
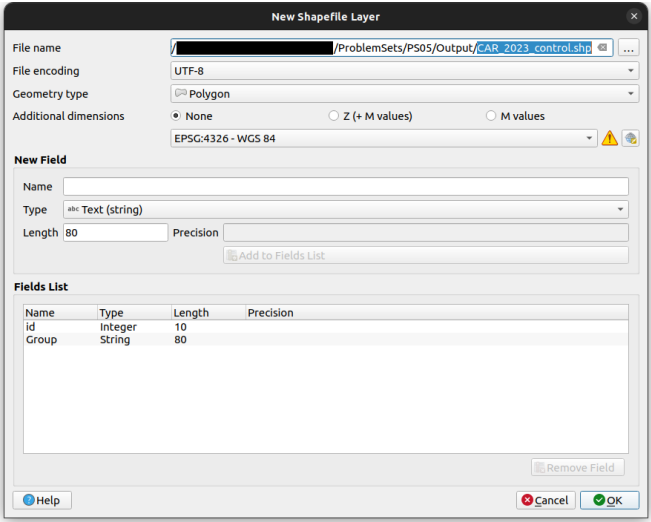
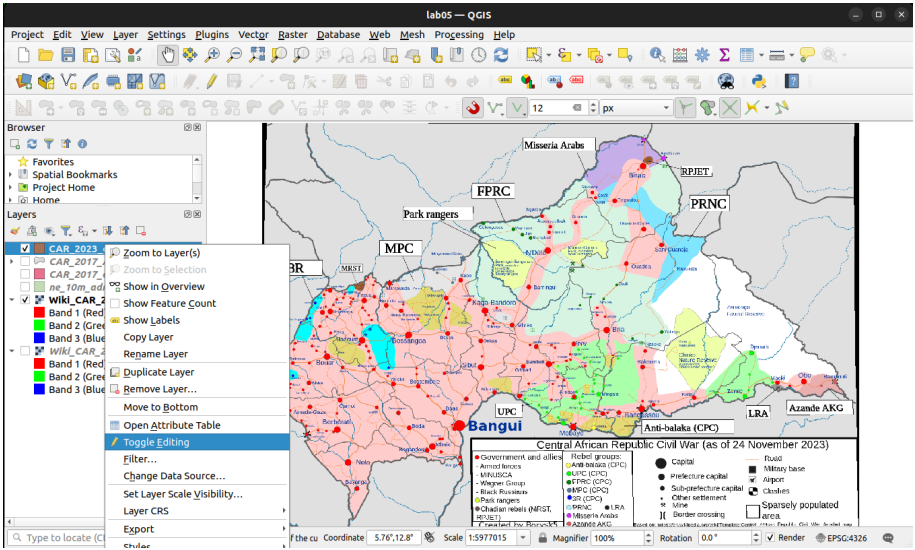


Figure 8: Can you make this map?

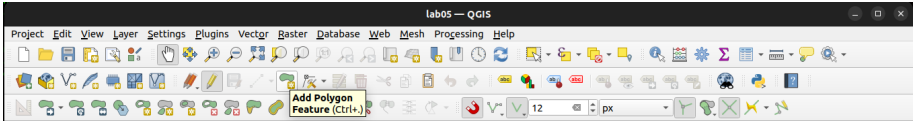
Let's *preview some of the steps*. Create a `New Shapefile Layer` for 2023: `CAR_2023_control.shp` (other parameters same as before)



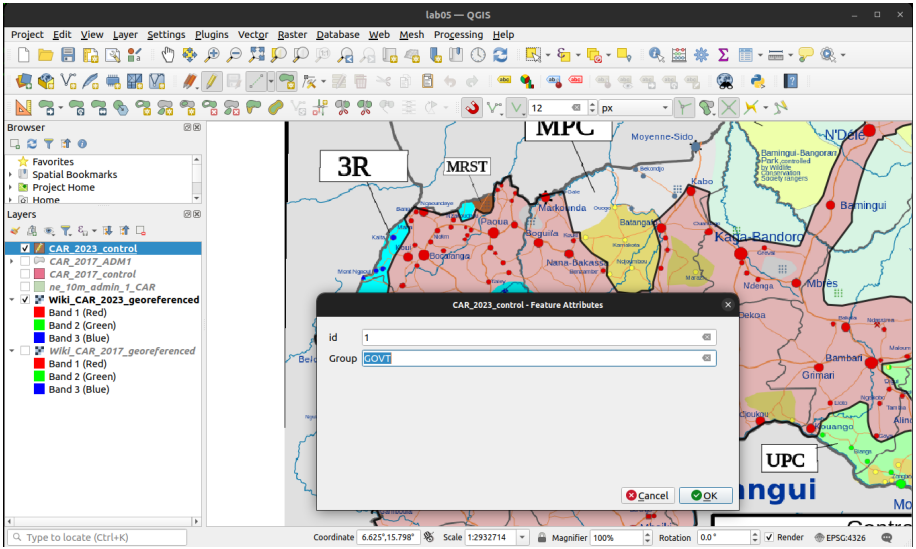
Set the layer to *editing mode* by `Right-clicking` → `Toggle Editing`



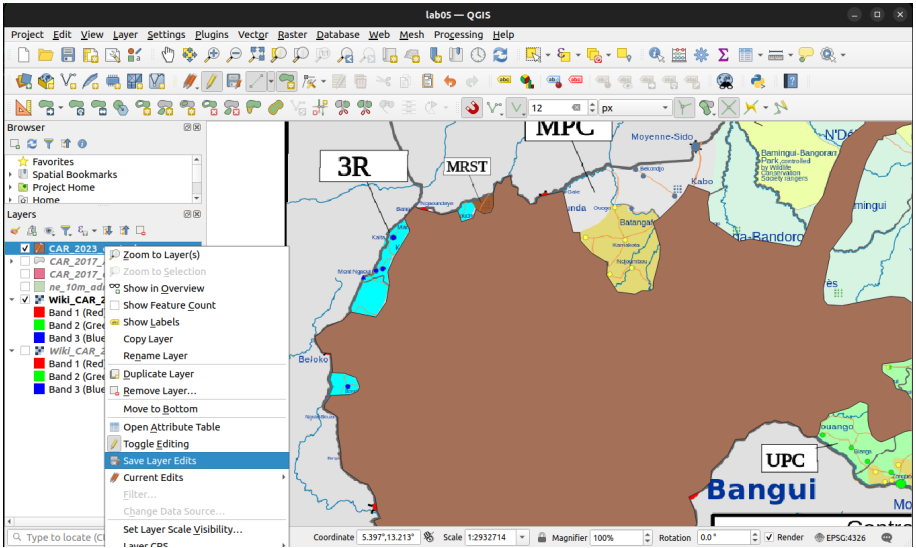
Click on the `Add Polygon Feature` tool. The snapping parameters should be the same as before



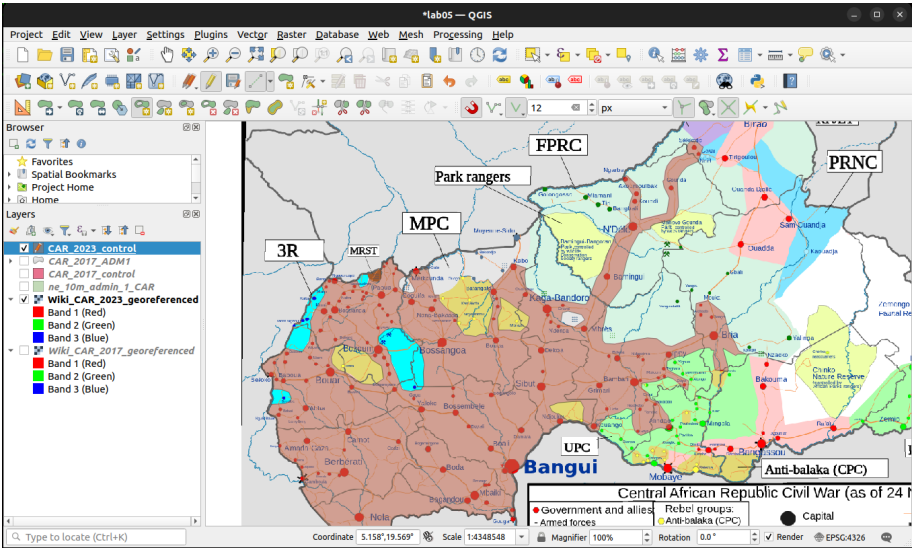
Trace new polygon features and enter field information like before (remember to hide the inactive layers while you do this)



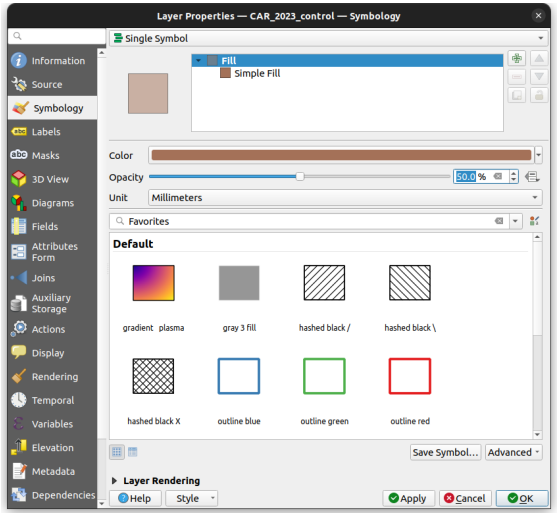
Save your progress as you go.



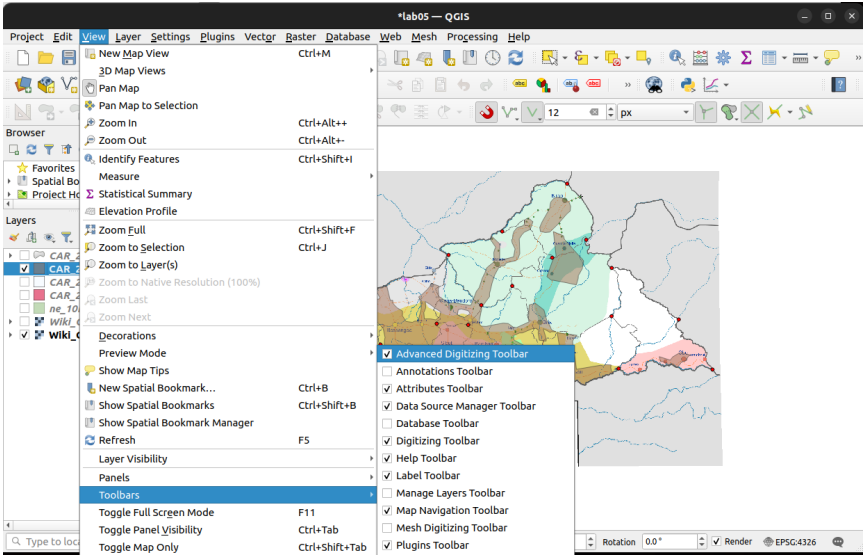
But how do we *create holes in polygons* to account for more complex geometries?



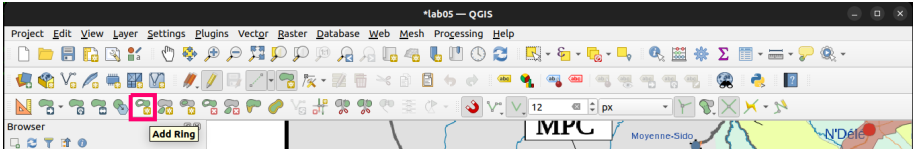
Start by making the `CAR_2023_control` layer semi-transparent (`Opacity` = 50%), so we can see the raster underneath



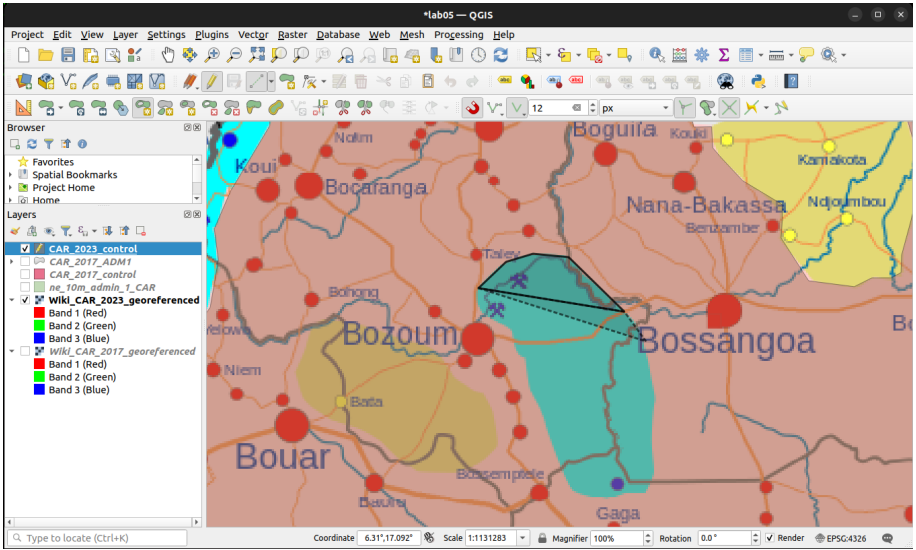
The tool we need is in the Advanced Digitizing Toolbar. To access it, go to `View` → `Toolbars` → check box next to `Advanced Digitizing Toolbar`



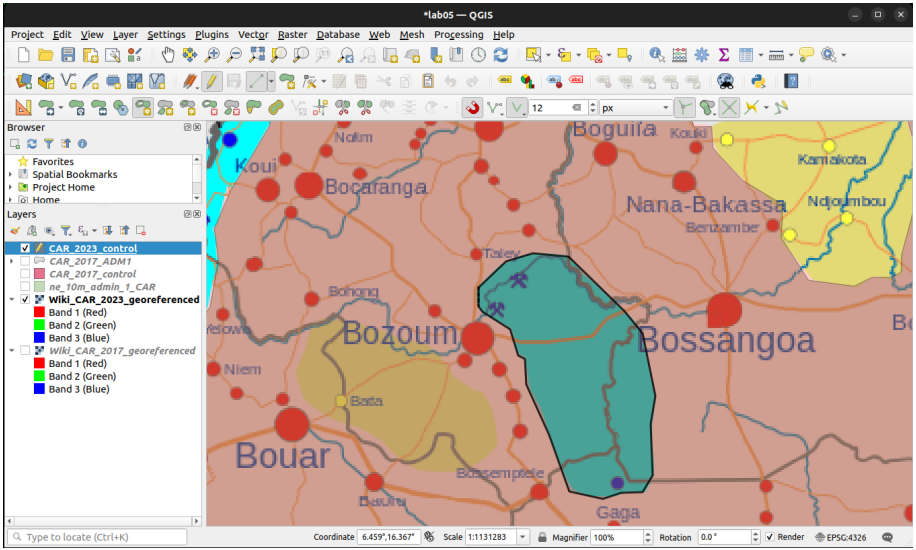
Click on `Add Ring` tool in the Advanced Digitizing Toolbar
(green blob with a hole in it, yellow star)



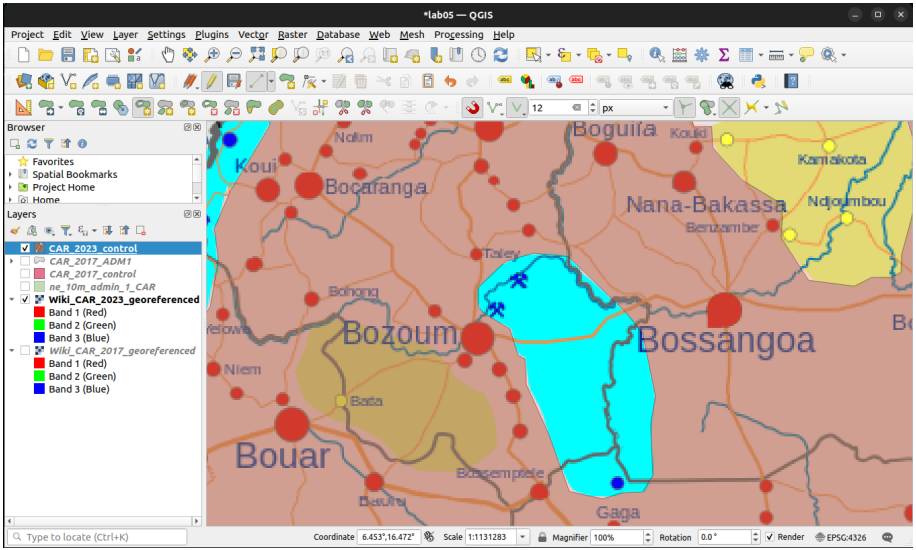
Using the `Add Ring` tool, trace the contour of the first polygon hole, as if you were tracing another polygon



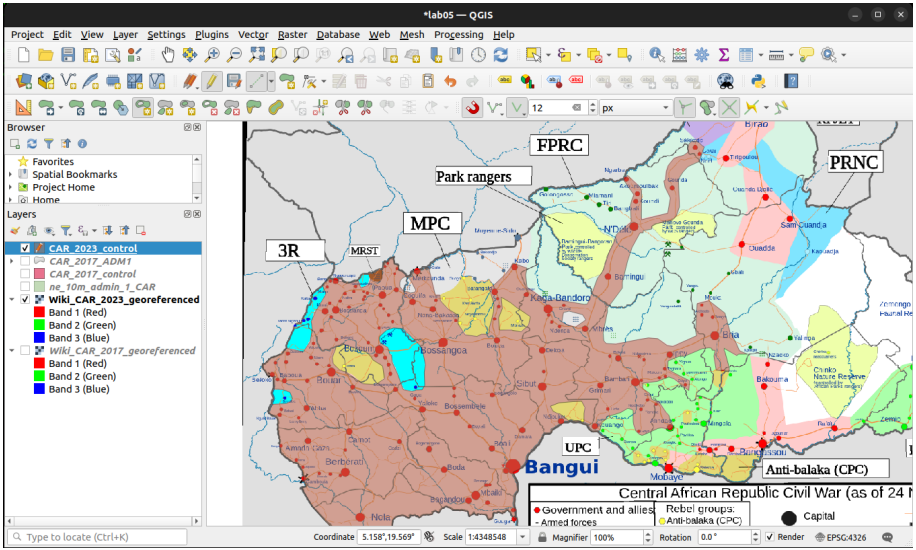
To close the loop, `right-click` anywhere on the screen



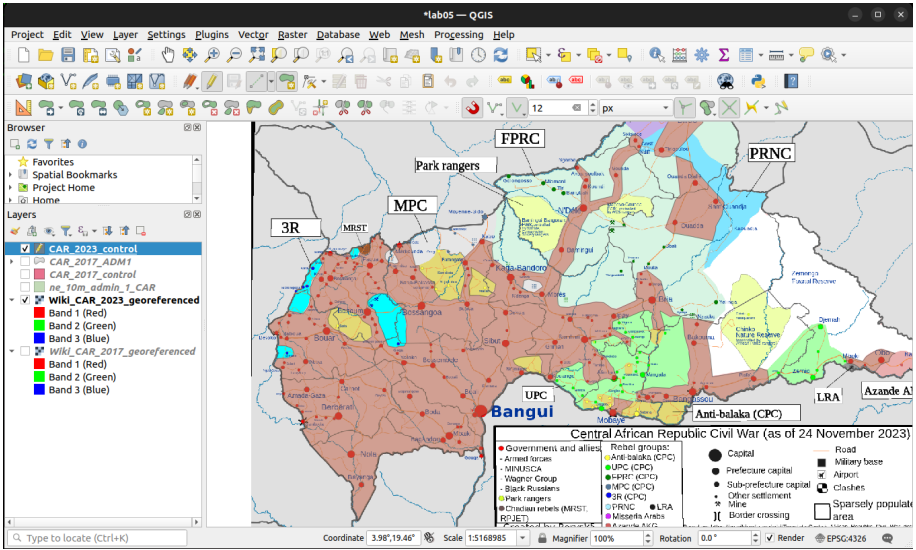
This should add a hole to the polygon you had vectorized



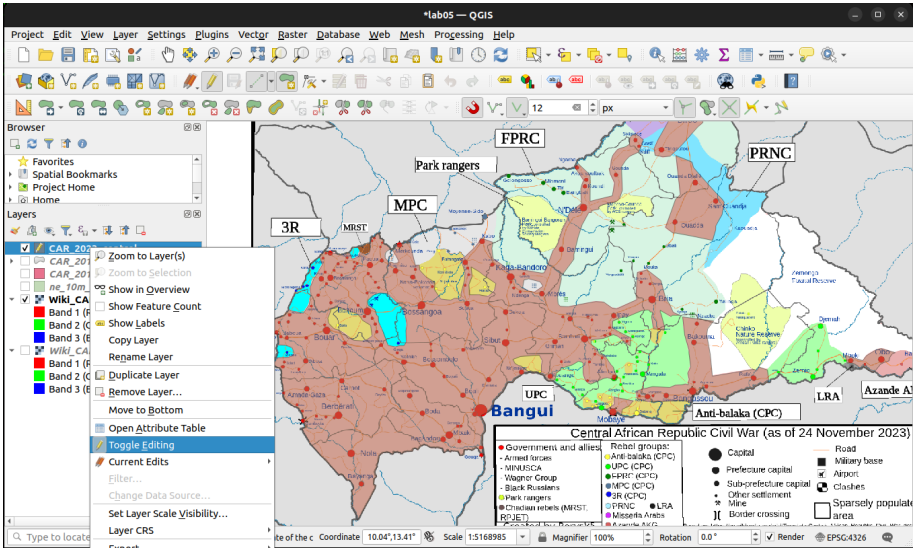
Repeat this process for each hole you need to carve out



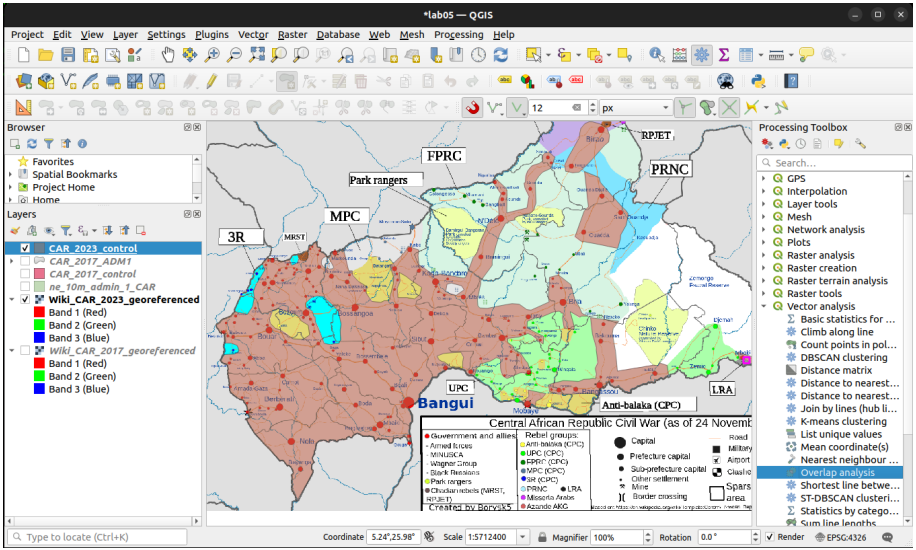
Add the remaining government-controlled polygons (there should be 6 non-contiguous government polygons here)



Save your progress and leave editing mode

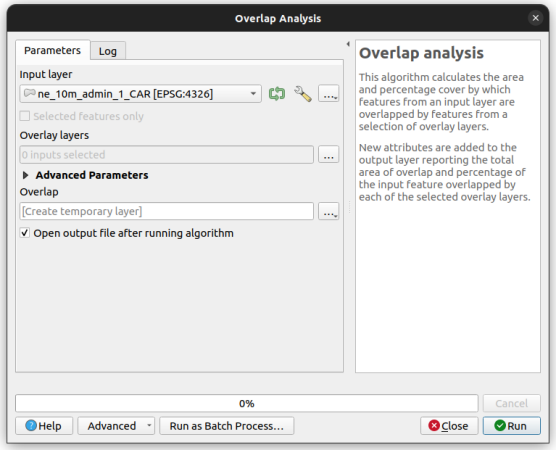


Go back to the `Overlap analysis` tool



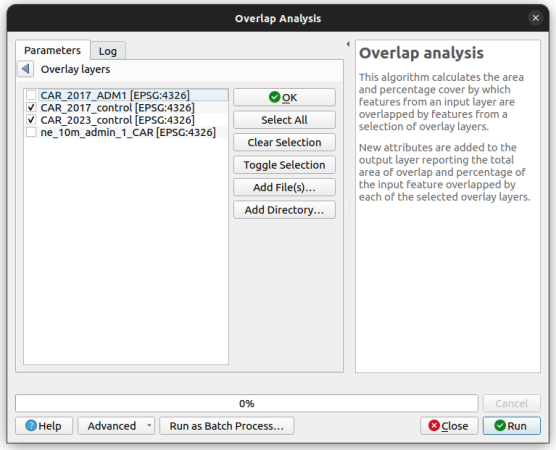
In the Overlap Analysis window, set

- `Input layer` = `ne_10m_admin_1_CAR`



Set

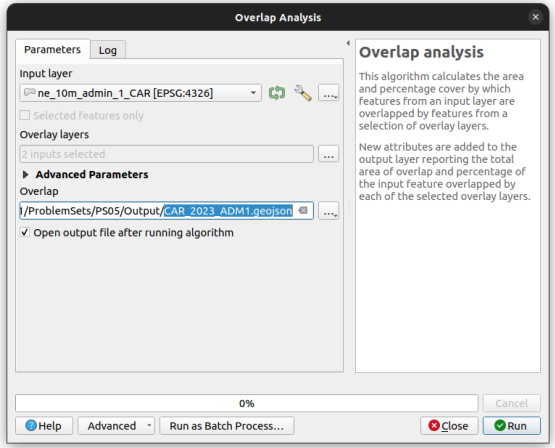
- `Overlay layers` = `CAR_2017_control`, `CAR_2023_control` (select both)



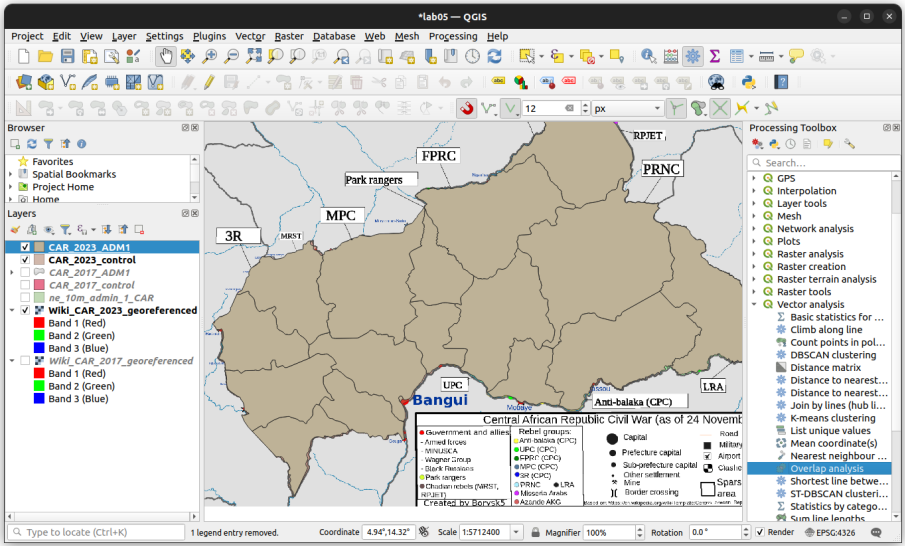
Set

- `Overlap` (file output) = `CAR_2023_ADM1.geojson` in `Output` folder.

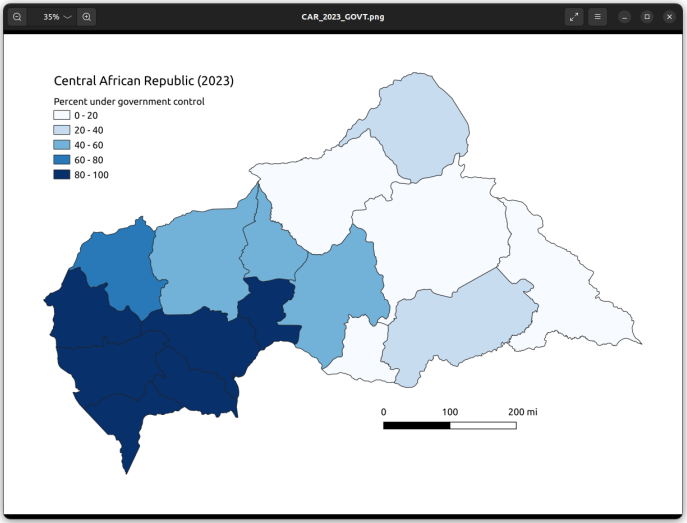
Click `Run`



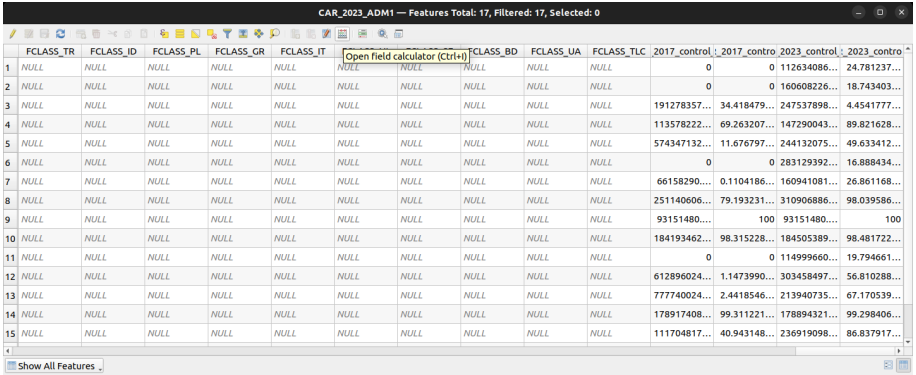
The new layer `CAR_2023_ADM1` should appear in the map and Layer menu



If you want, you can use this map to create the 2023 counterpart to the first image we created (for practice only; this in not required and not part of the assignment)

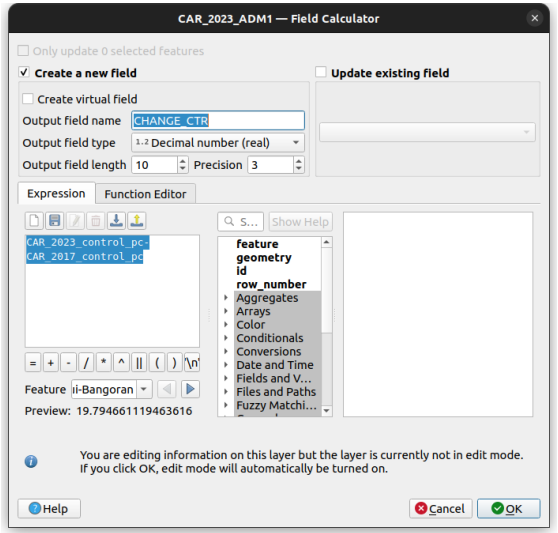


Let's *calculate the difference between 2023 and 2017*. Open the `Attribute Table` for `CAR_2023_ADM1`, go to `Field Calculator`



	FCLASS_TR	FCLASS_ID	FCLASS_PL	FCLASS_GR	FCLASS_IT	FCLASS_BD	FCLASS_UA	FCLASS_TLC	2017_control	2017_contro	2023_control	2023_contro
1	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	0	0	112634086…	24.781237…
2	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	0	0	160608226…	18.743403…
3	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	191278357…	34.418479…	247537898…	4.4541777…
4	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	113578222…	69.263207…	147290043…	89.821628…
5	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	574347132…	11.676797…	244132075…	49.633412…
6	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	0	0	283129392…	16.888434…
7	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	66158290.…	0.1104186…	160941081…	26.861168…
8	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	251140606…	79.193231…	310906886…	98.039586…
9	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	93151480.…	100	93151480.…	100
10	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	184193462…	98.315228…	184505389…	98.481722…
11	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	0	0	114999660…	19.794661…
12	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	612896024…	1.1473990…	303458497…	56.810288…
13	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	777740024…	2.4418546…	213940735…	67.170539…
14	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	178917408…	99.311221…	178894321…	99.298406…
15	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	111704817…	40.943148…	236919098…	86.837917…

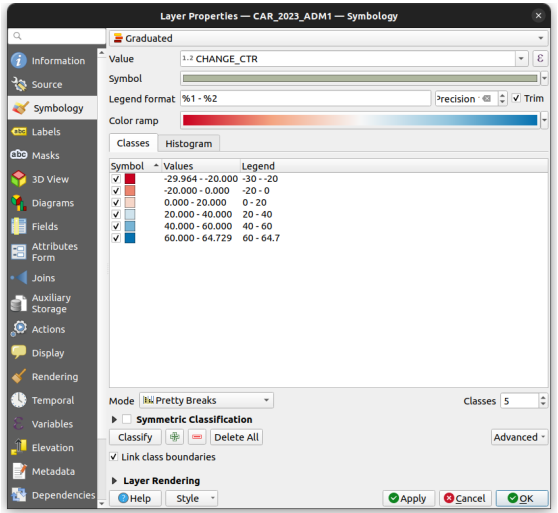
Create new field called `CHANGE_CTR` of type `Decimal number (real)`. For the `Expression`, write `CAR_2023_control_pc - CAR_2017_control_pc`. Click `OK`



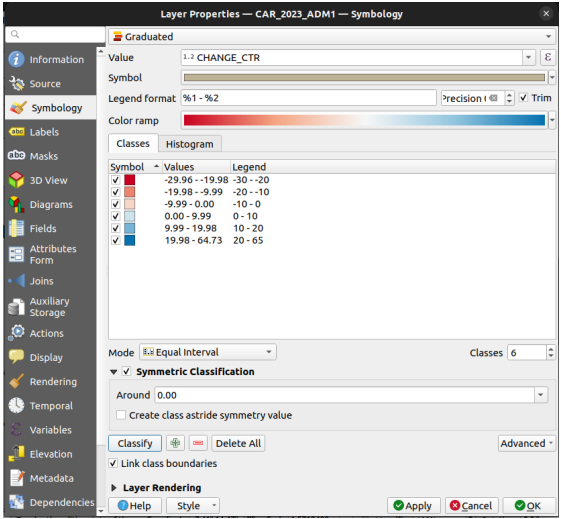
Map this new variable. In `Properties`, set

- `Symbology type` = `Graduated`
- `Value` = `CHANGE_CTR`
- `Color ramp` = `All Color Ramps` → `RdBu`

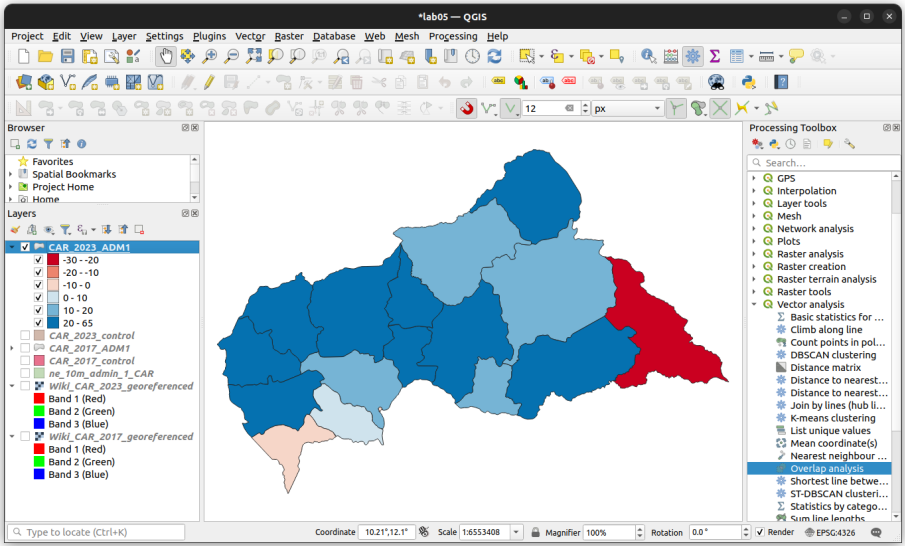
Try setting `Mode` = `Pretty Breaks`. Click `Classify`.
Check to make sure the breaks are *centered on 0* (as they are here). If not...



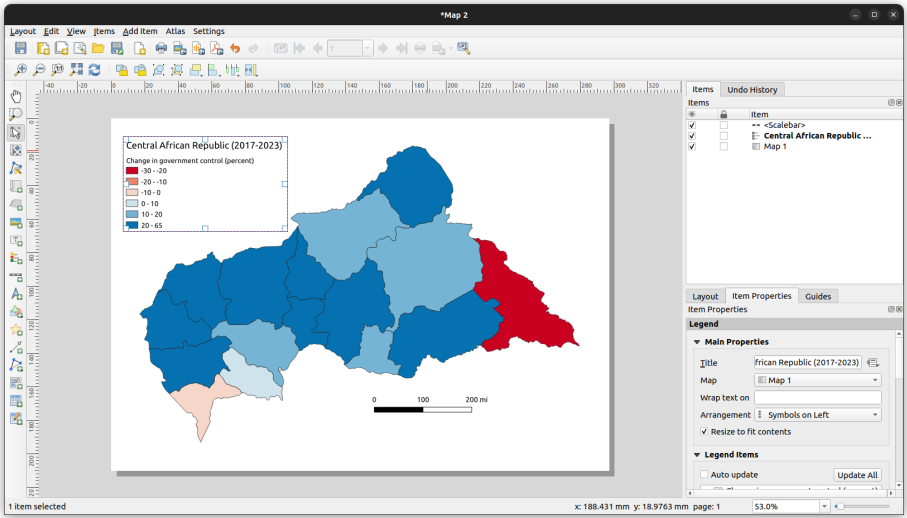
If `Pretty Breaks` are not centered on 0, switch to `Equal Interval` with `Symmetric Classification` set to `Around` $= 0$. Click `Classify`



When you're done, the distribution of colors should look roughly like this



At this point, you're ready to create a `New Print Layout`, export, and you're done



This is what the exported `png` file should look like. Good luck!