

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

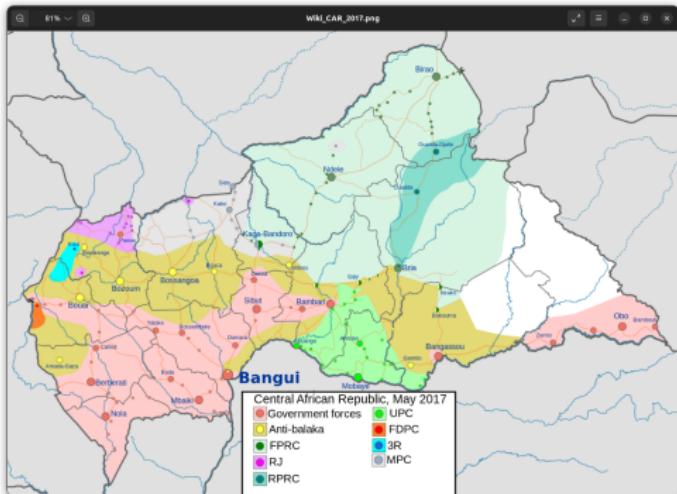


Figure 1: Territorial control in CAR, 2017

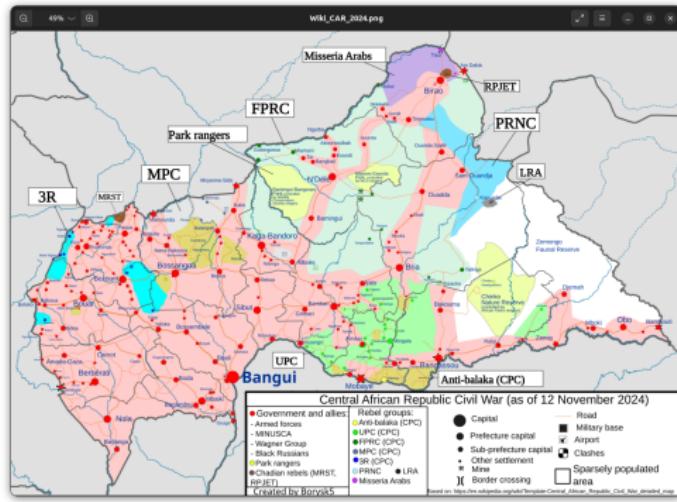


Figure 2: Territorial control in CAR, 2024

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



Africa

Wagner troops arrive in Central African Republic ahead of referendum

By Judicael Yongo

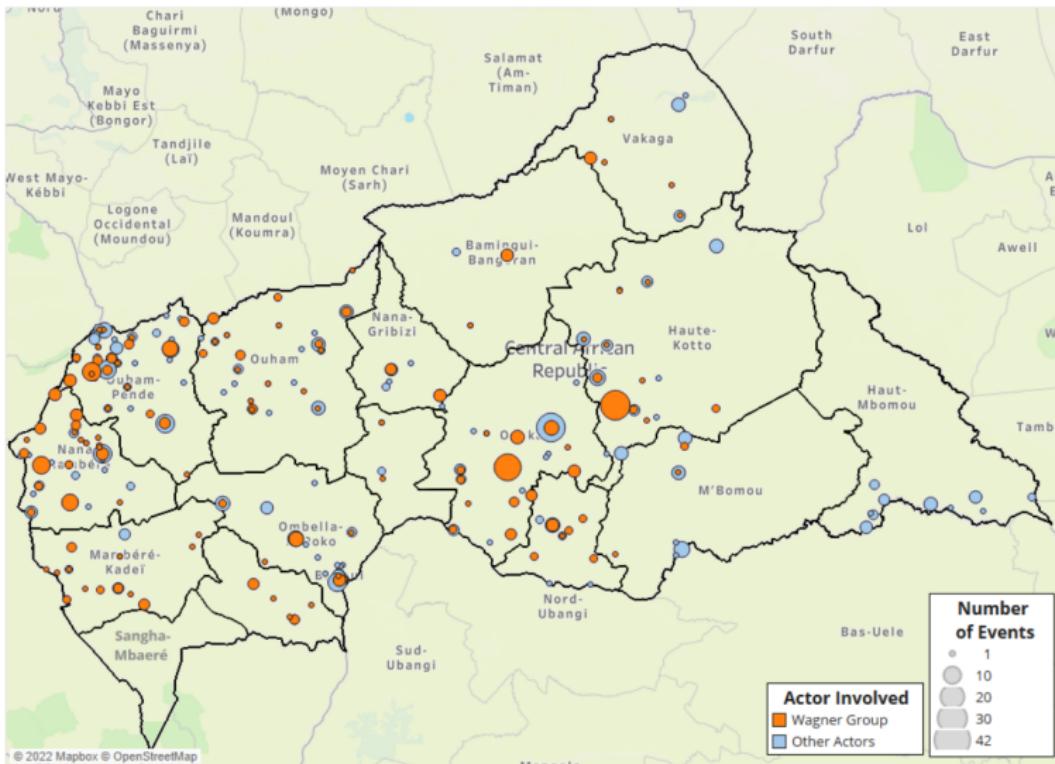
July 17, 2023 1:34 PM EDT - Updated 6 months ago



[1/2] Russian officers from the wagner group are seen around Central African president Faustin-Archange Touadera, as they are part of the presidential security system during the referendum campaign to change the constitution and remove



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

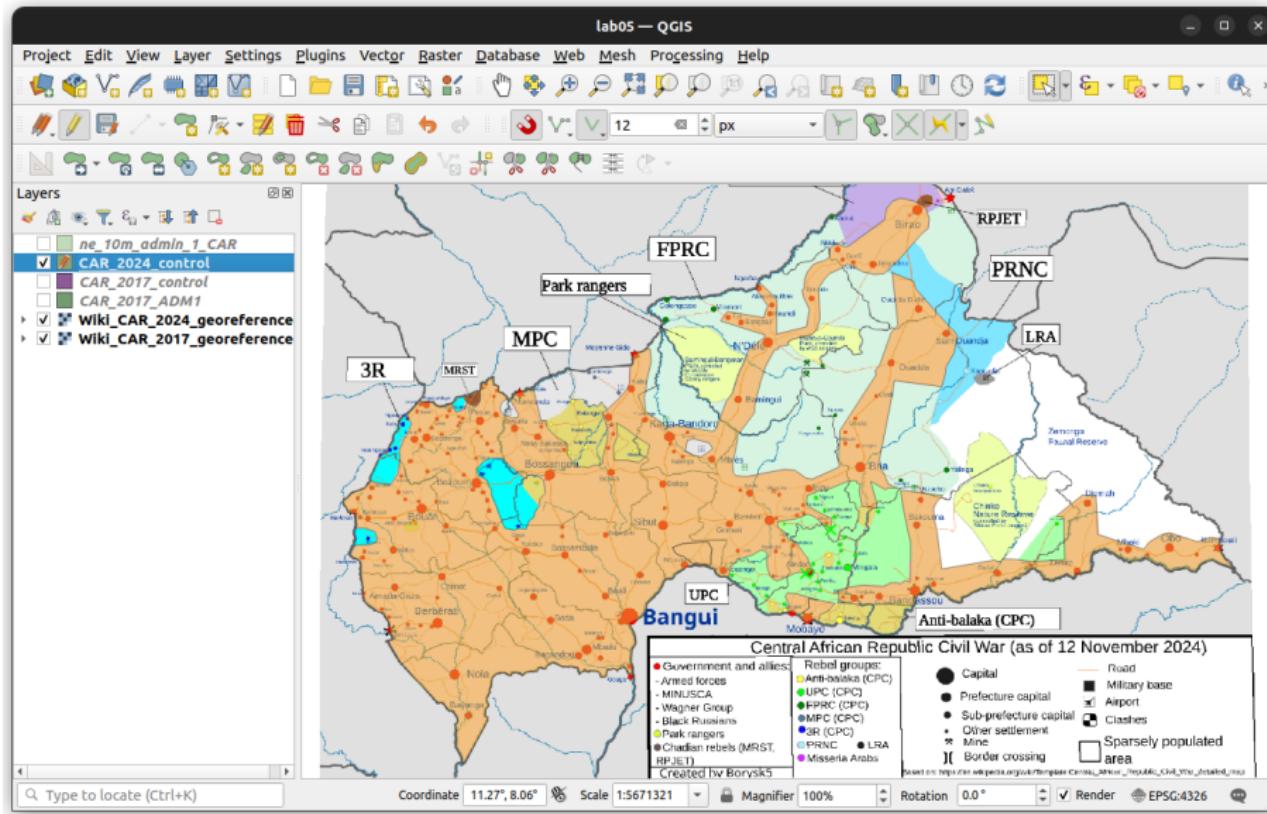
1. Lab exercise

- a) Georeference 2017 map (new method)
- b) Re-use GCPs to georeference 2024 map
- c) Create new polygon layer for government control

2. Problem set

- a) Map comparing government control in 2024 to 2017

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



... to calculate percent of each province controlled by the CAR government in 2024

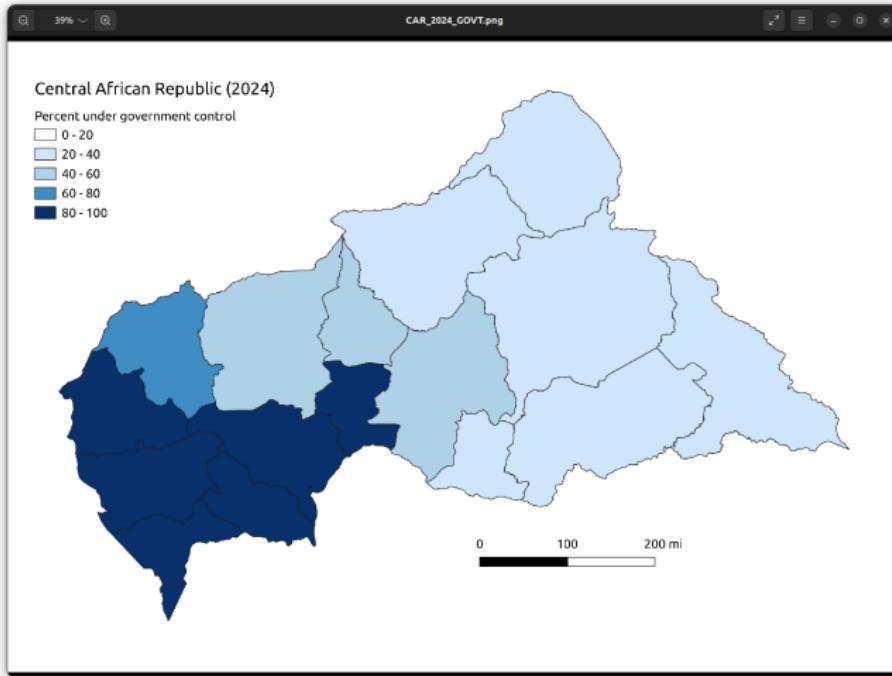


Figure 4: CAR government control, 2024

... and 2017

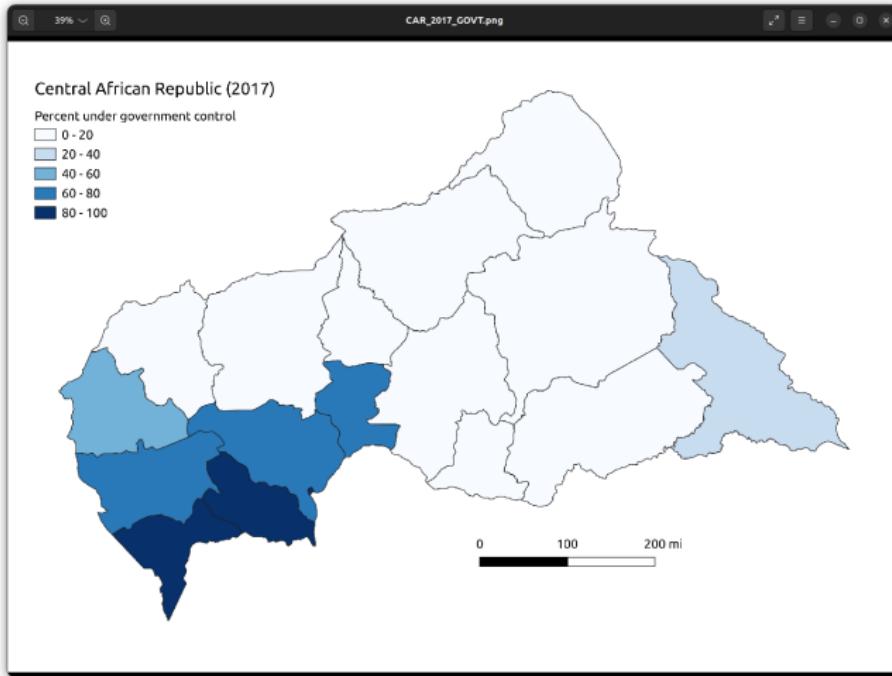


Figure 5: CAR government control, 2017

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

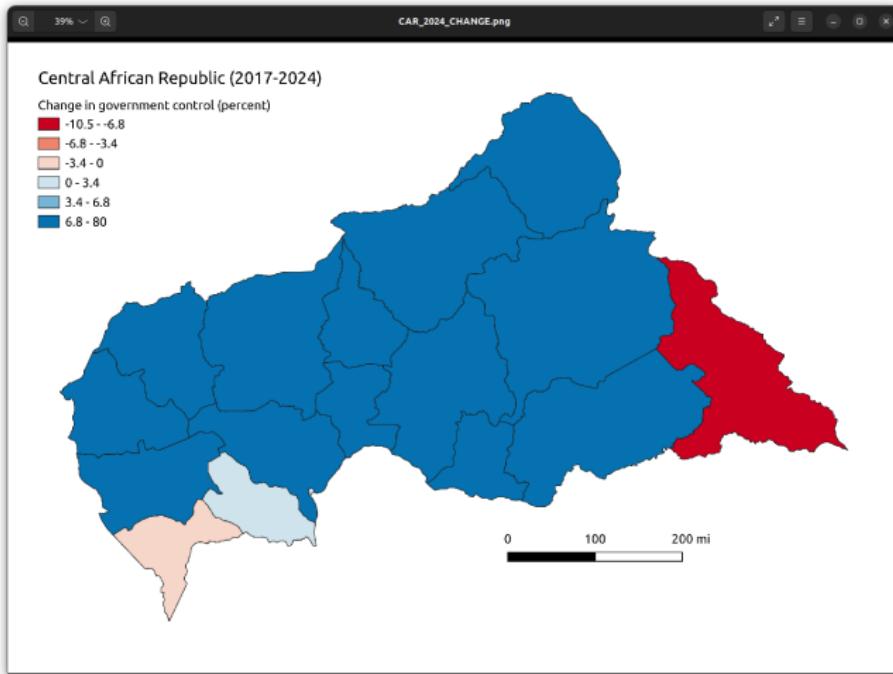


Figure 6: Save as CAR_2024_CHANGE.png

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

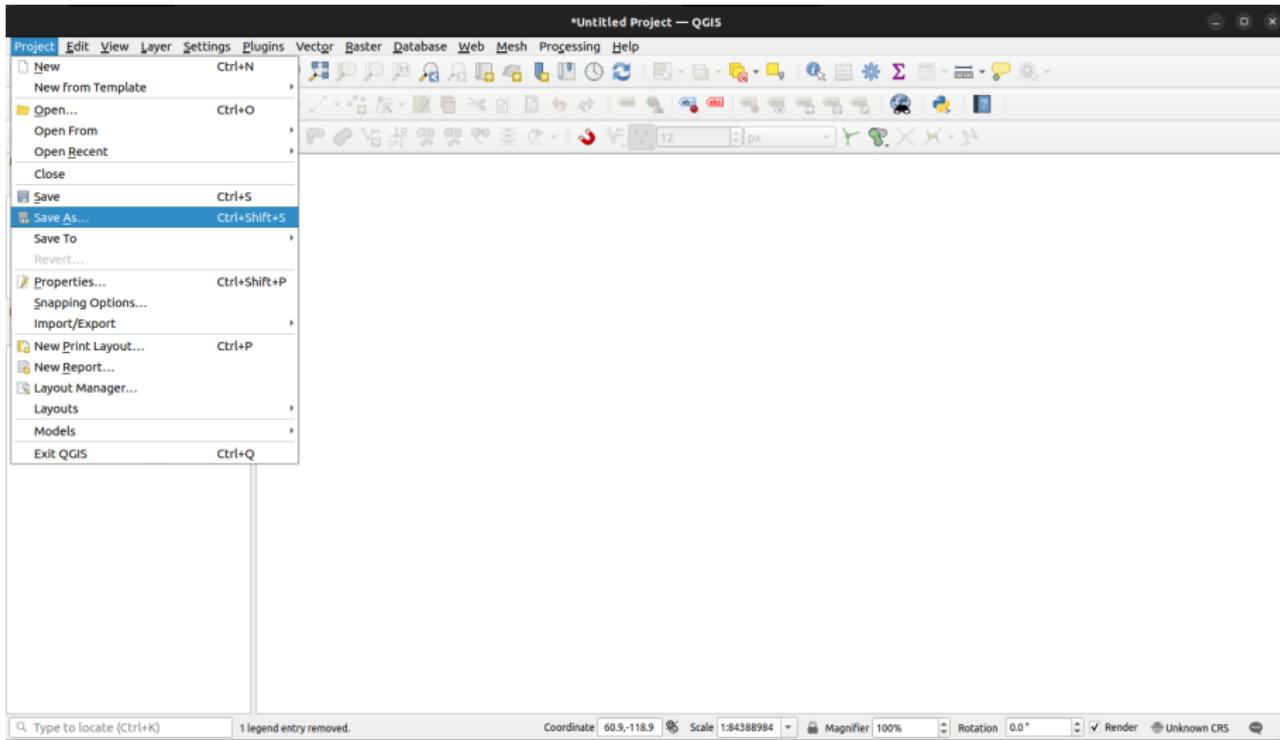
These are all in the Lab05PS05.zip file posted on Canvas.

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.

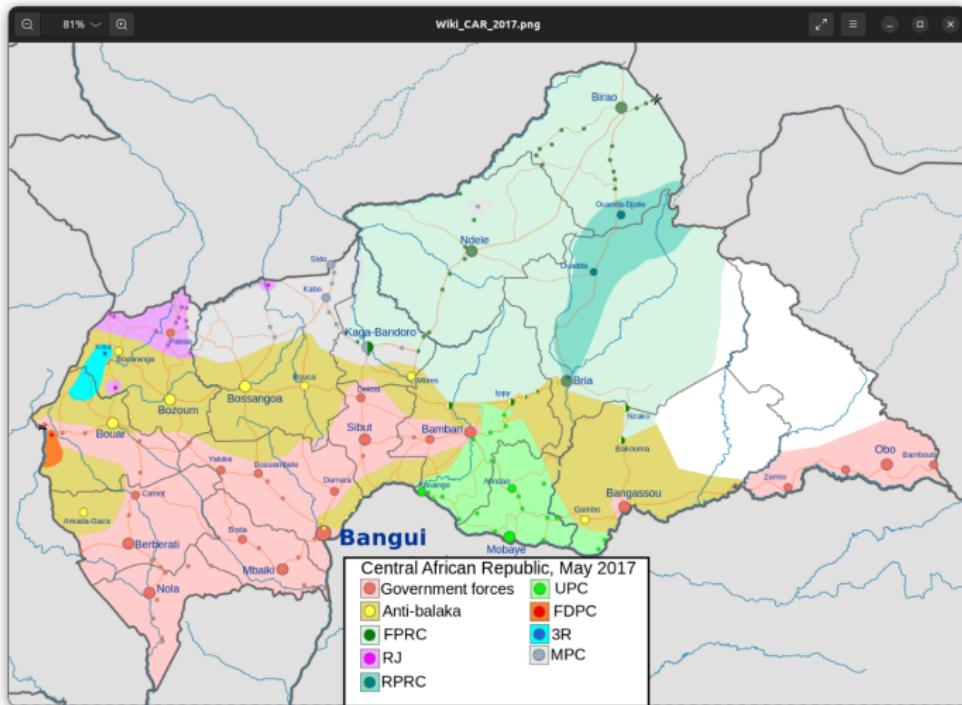
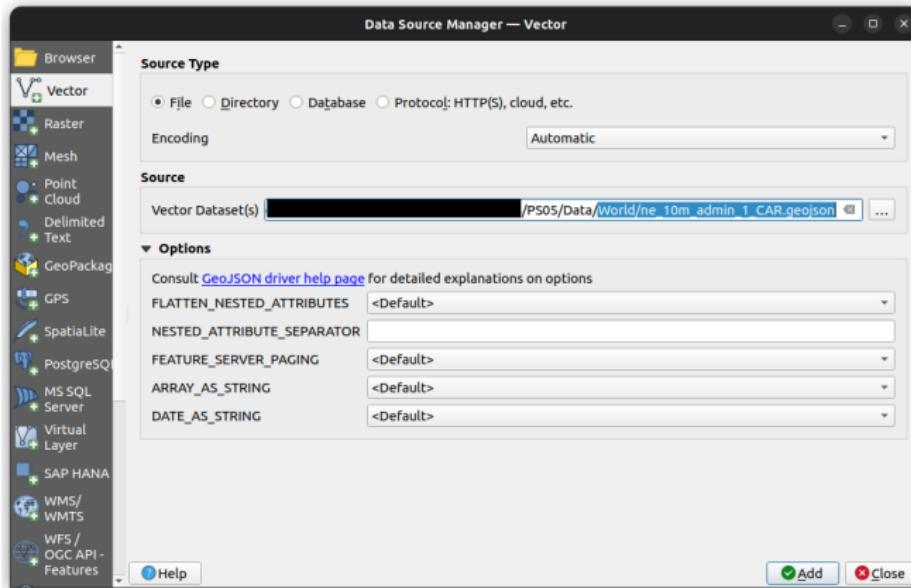


Figure 7: How can we georeference this?

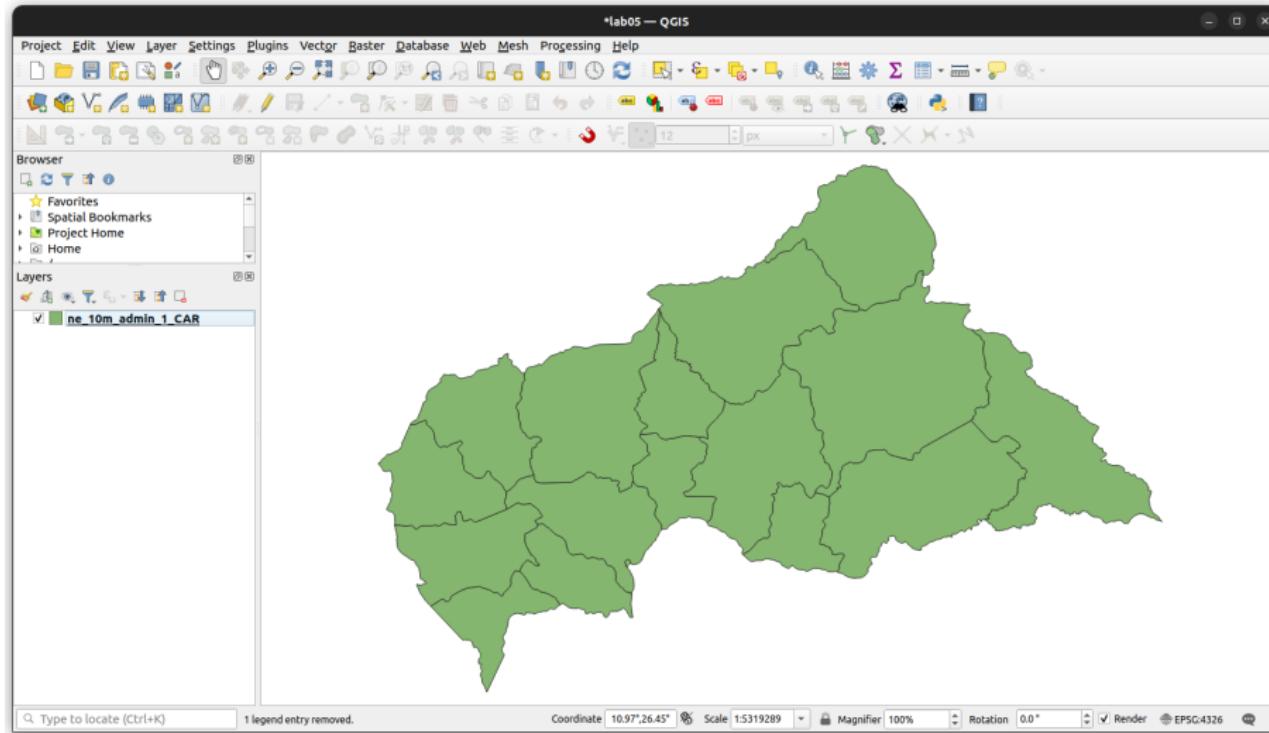
Let's open the basemap we'll be using for georeferencing.

Go to Layer → Add Layer → Add Vector Layer....

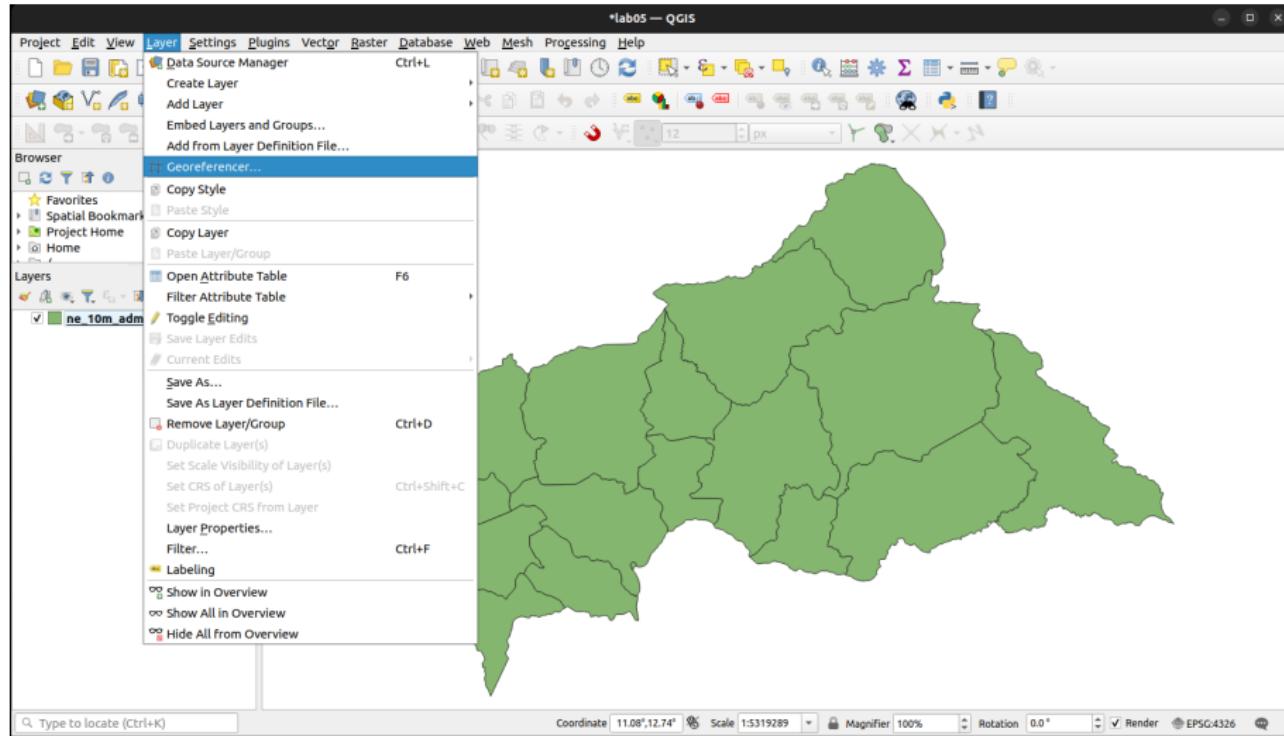
Navigate to ne_10m_admin_1_CAR.geojson in Data/World



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

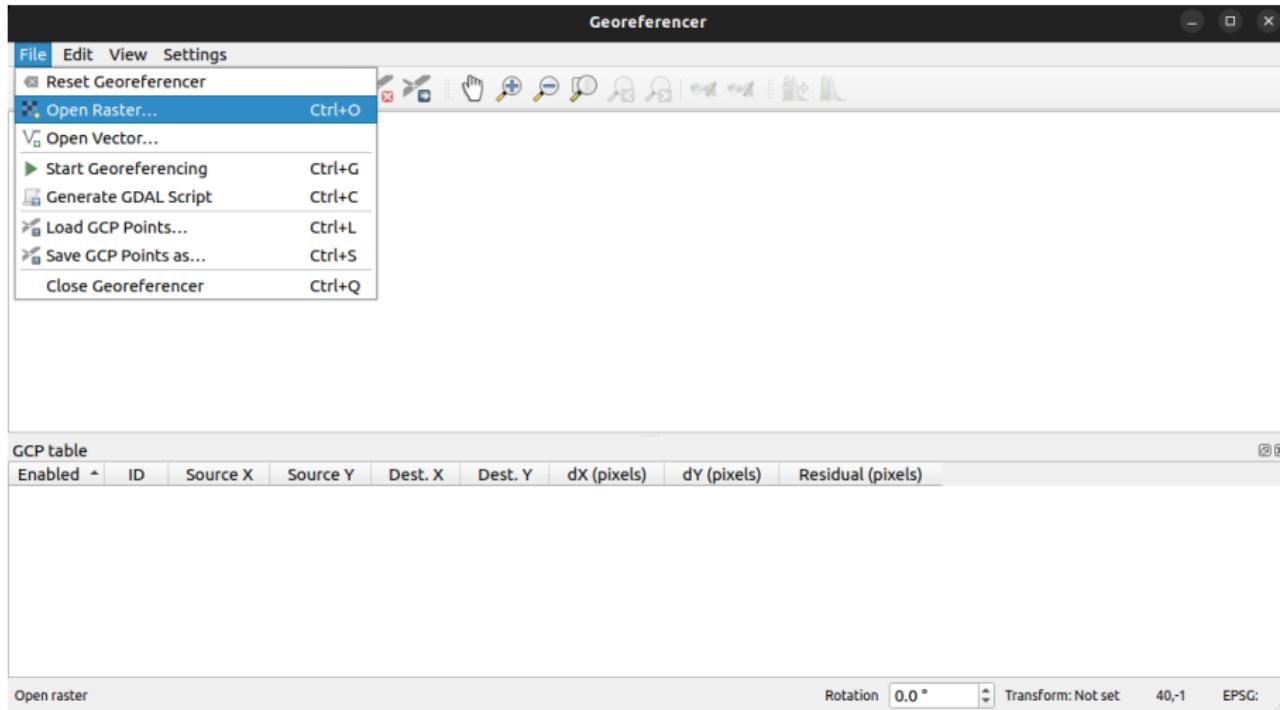


To open the georeferencer, click on Layer → Georeferencer

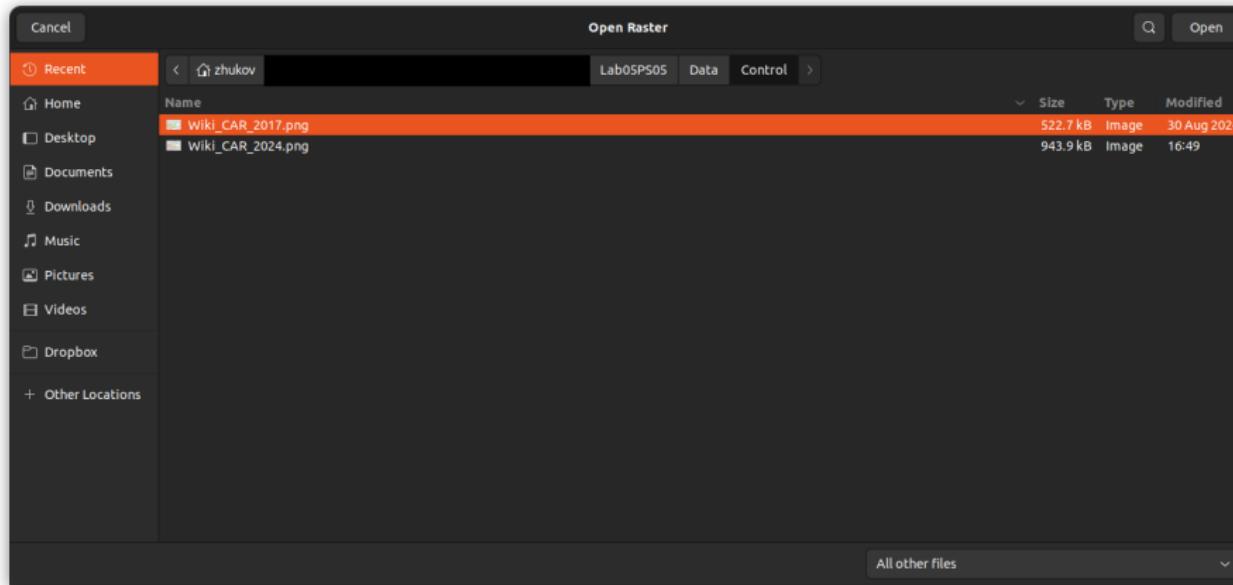


This will open an empty Georeferencer window.

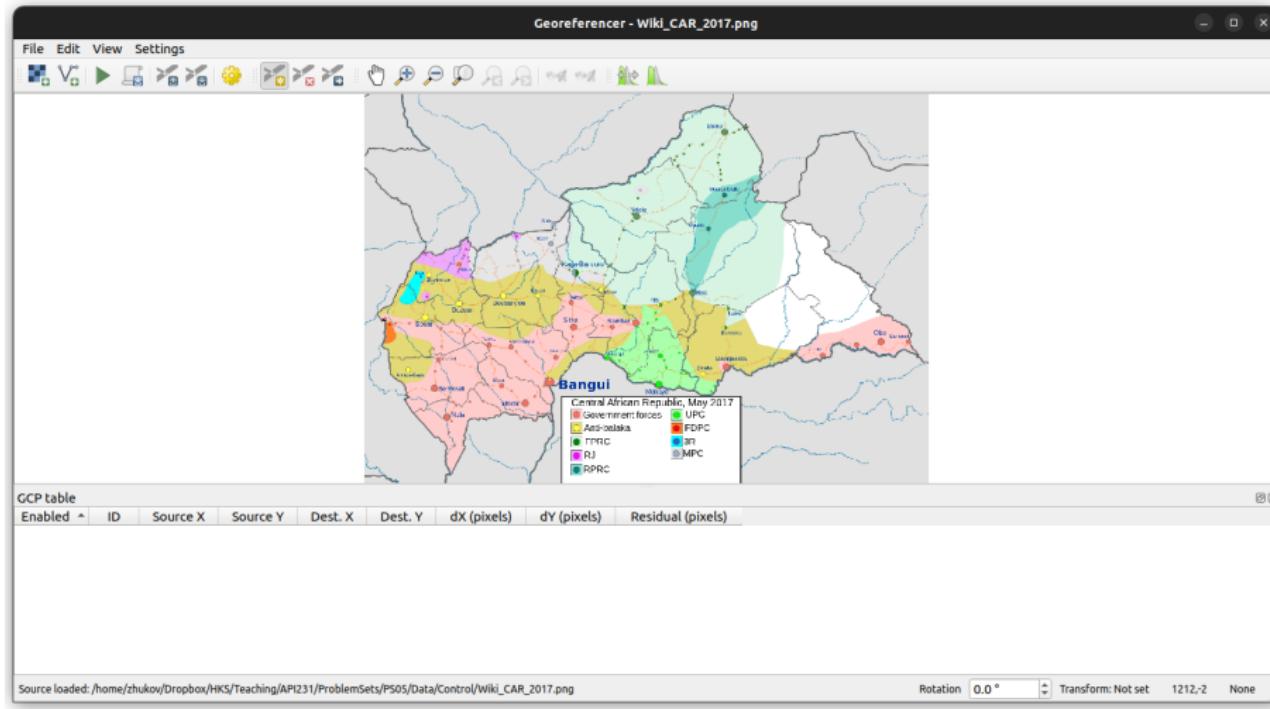
To open our PNG image, go to File → Open Raster



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



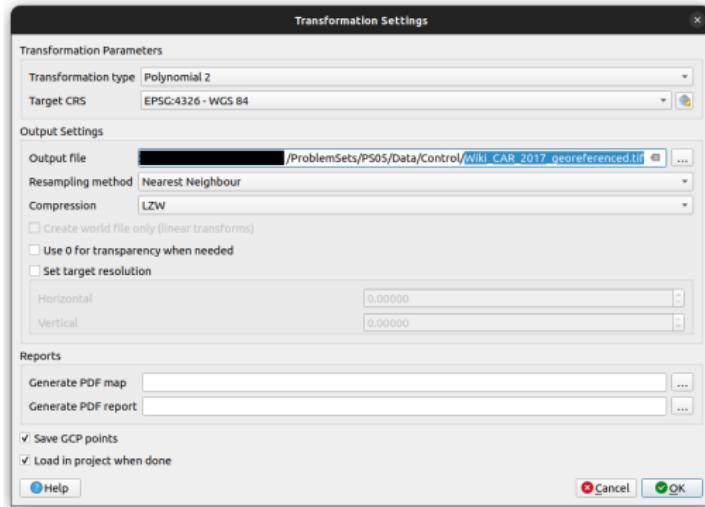
The map image will appear in the Georeferencer's top pane.



Go to Settings menu →
Transformation settings

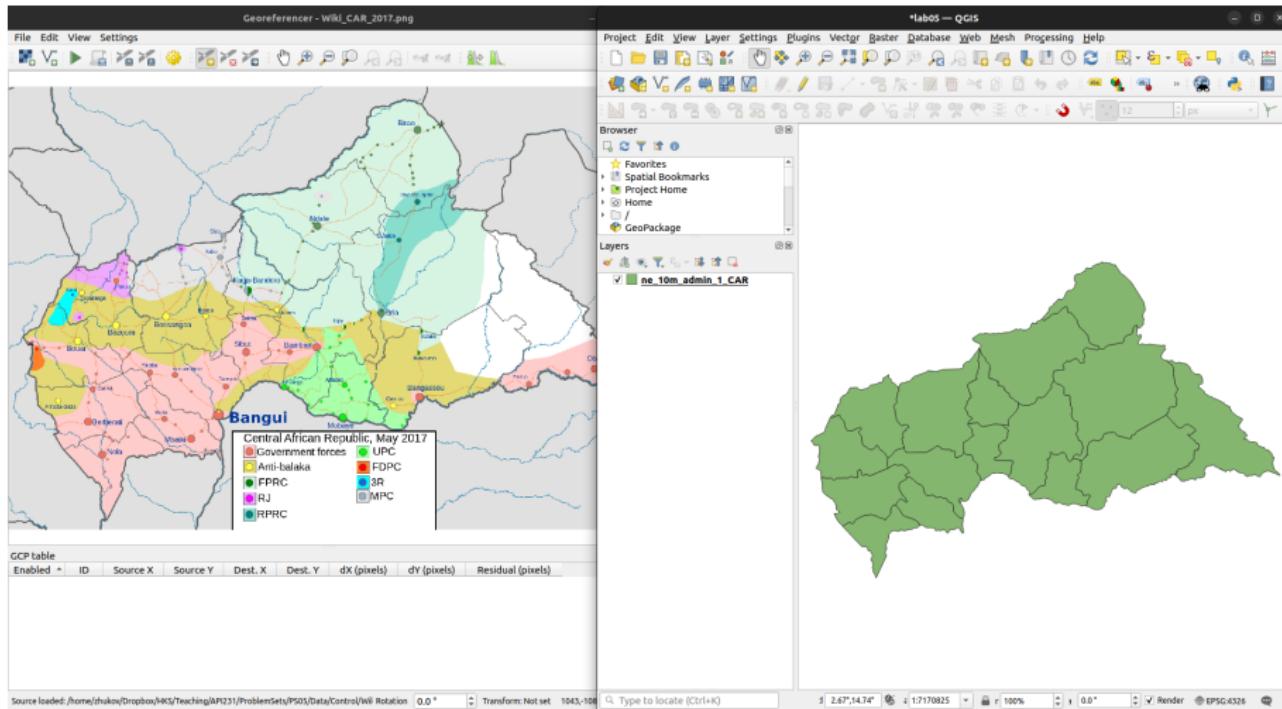
Set

- 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
- Uncheck Set target resolution
- ✓ Save GCP points
- ✓ Load in QGIS when done

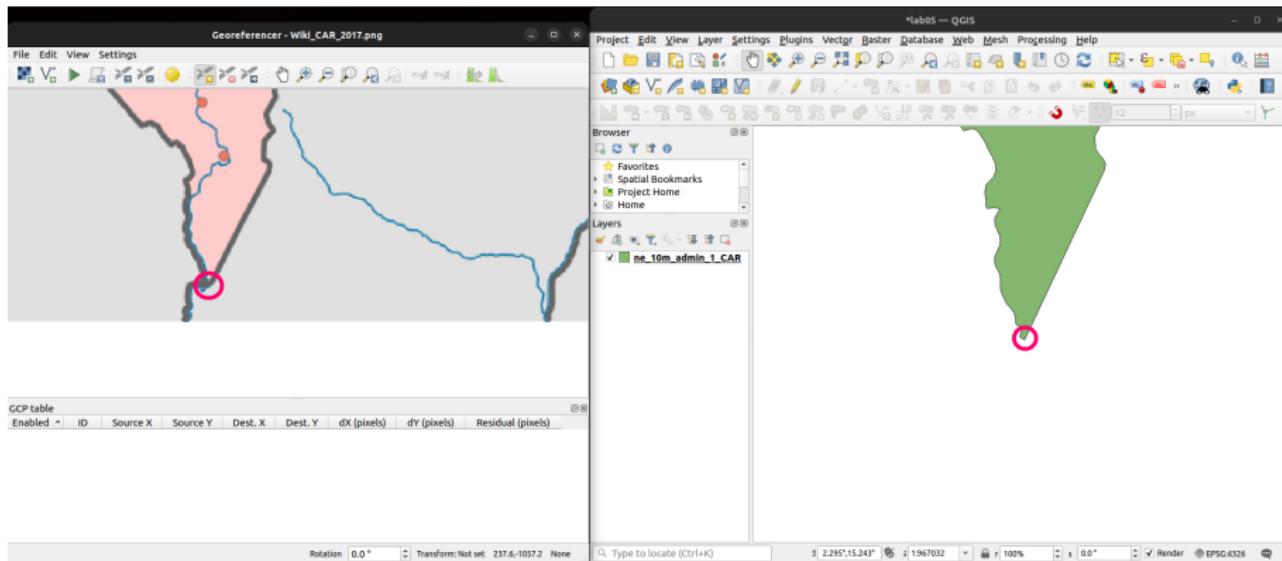


Click OK

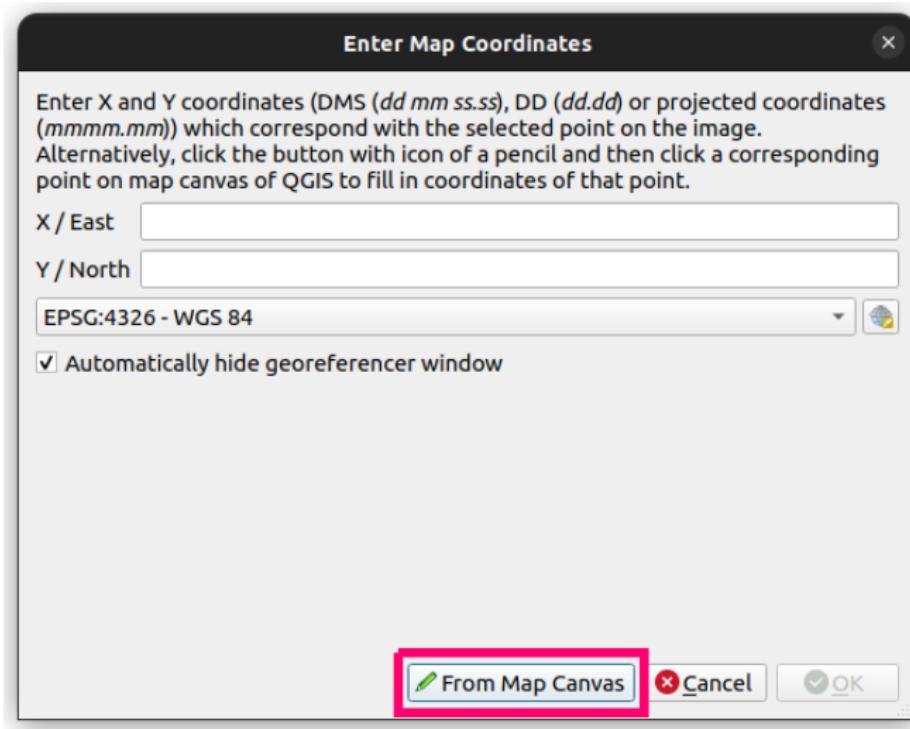
Try to set up the interface so that the Georeferencer window (left) and Project window (right) are both visible, or at least accessible, on your screen



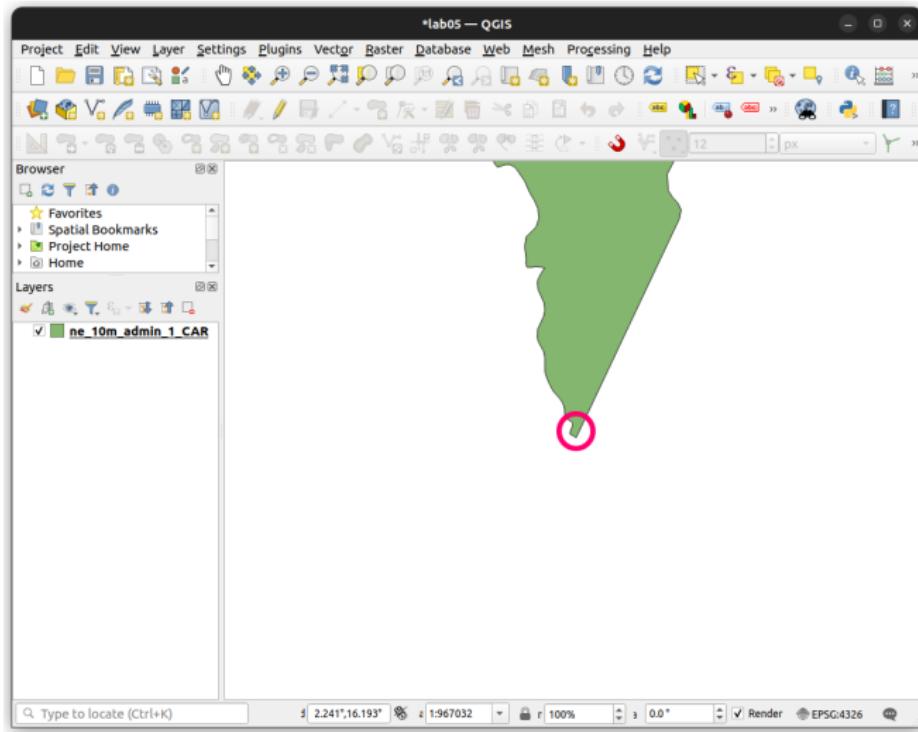
Let's place our first ground control point (GCP) at the southern-most tip of CAR.
Click the point marked in red in the Georeferencer (left)



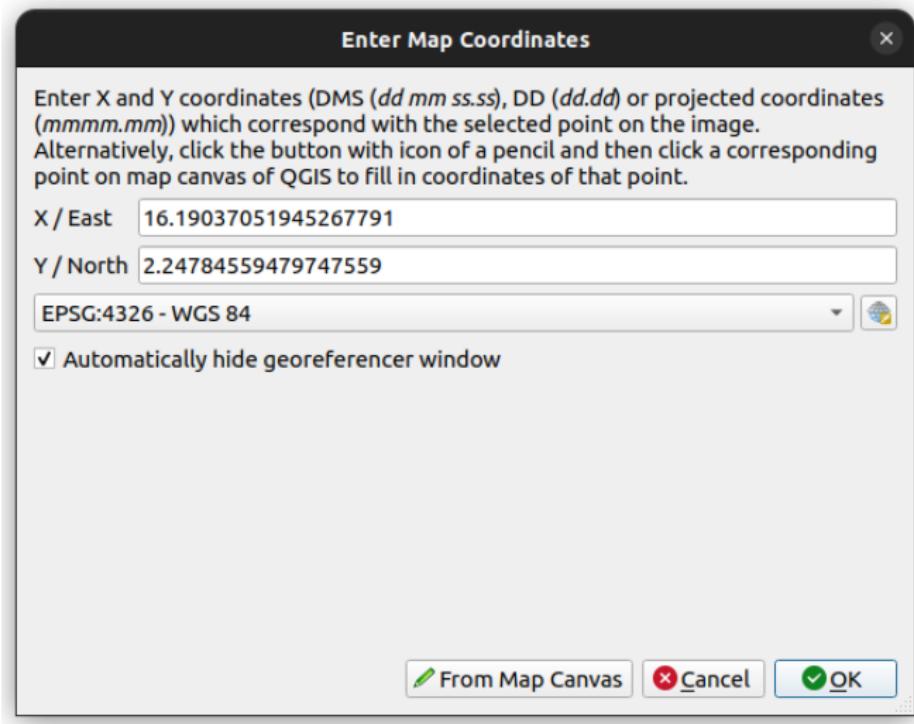
Rather than entering the *x* and *y* coordinates manually, click From Map Canvas



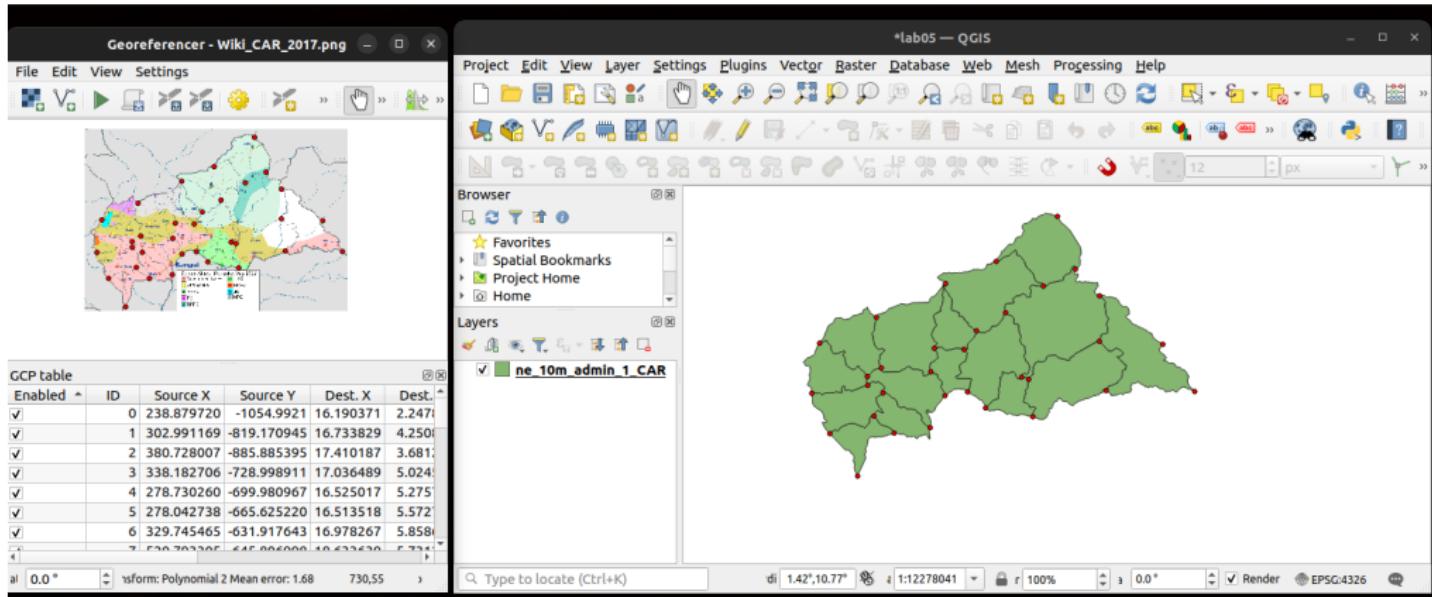
The view will switch to the Project window. Click the corresponding point on the administrative boundaries layer



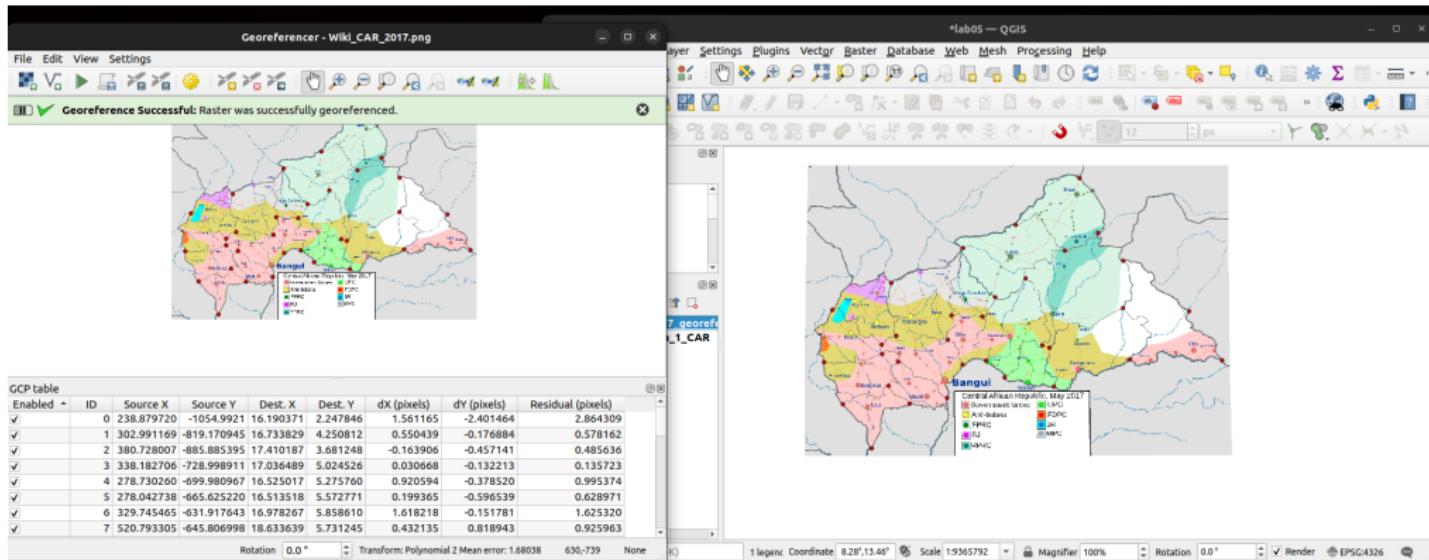
The coordinates you selected will automatically appear in the Enter Map Coordinates window. Click OK



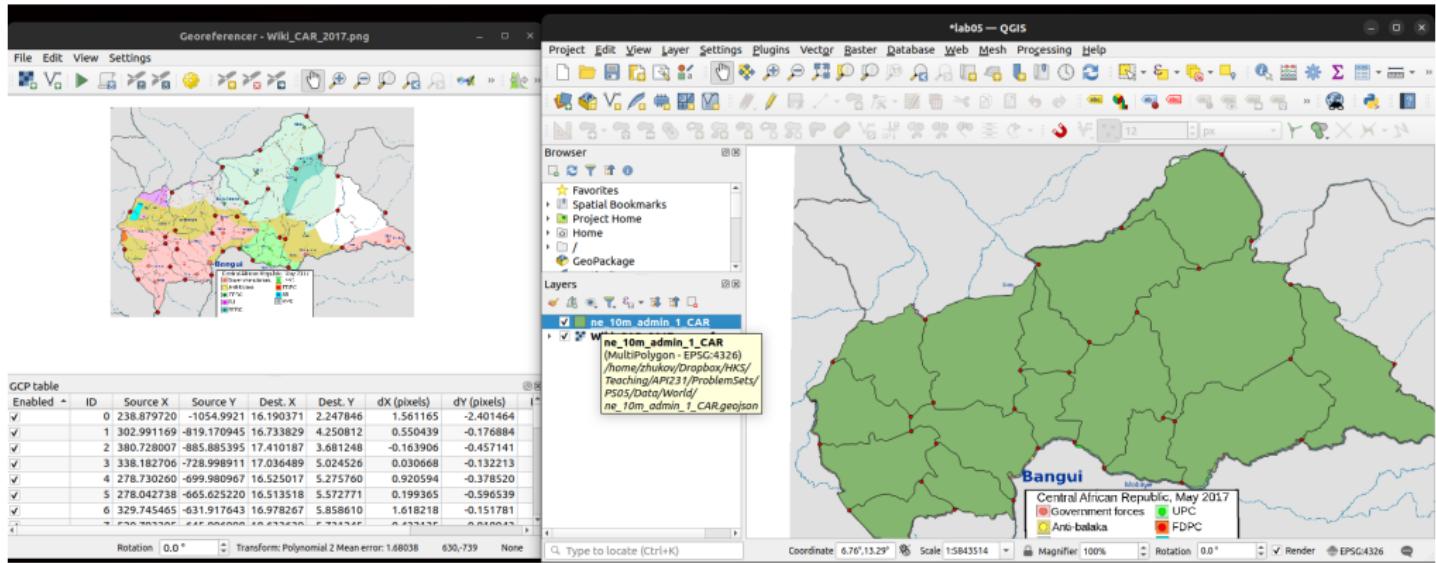
Repeat this process for every three-way provincial border intersection, and as many recognizable outer boundary points as possible, until the GCPs have broad coverage (there are 32 GCPs in the example shown here)



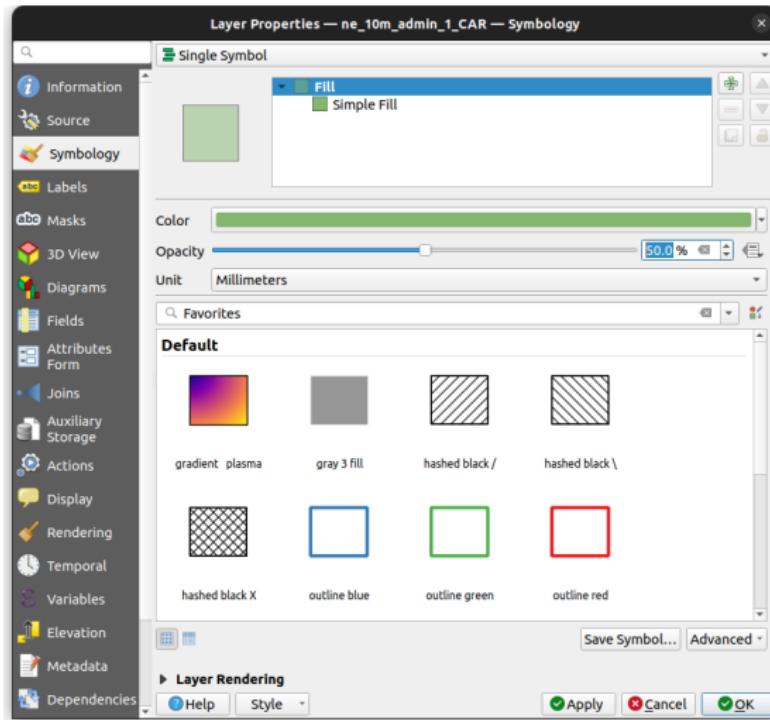
Once you have a critical mass of GCPs, click on Start georeferencing (►) button. If the process is successful, you will see a notification at the top



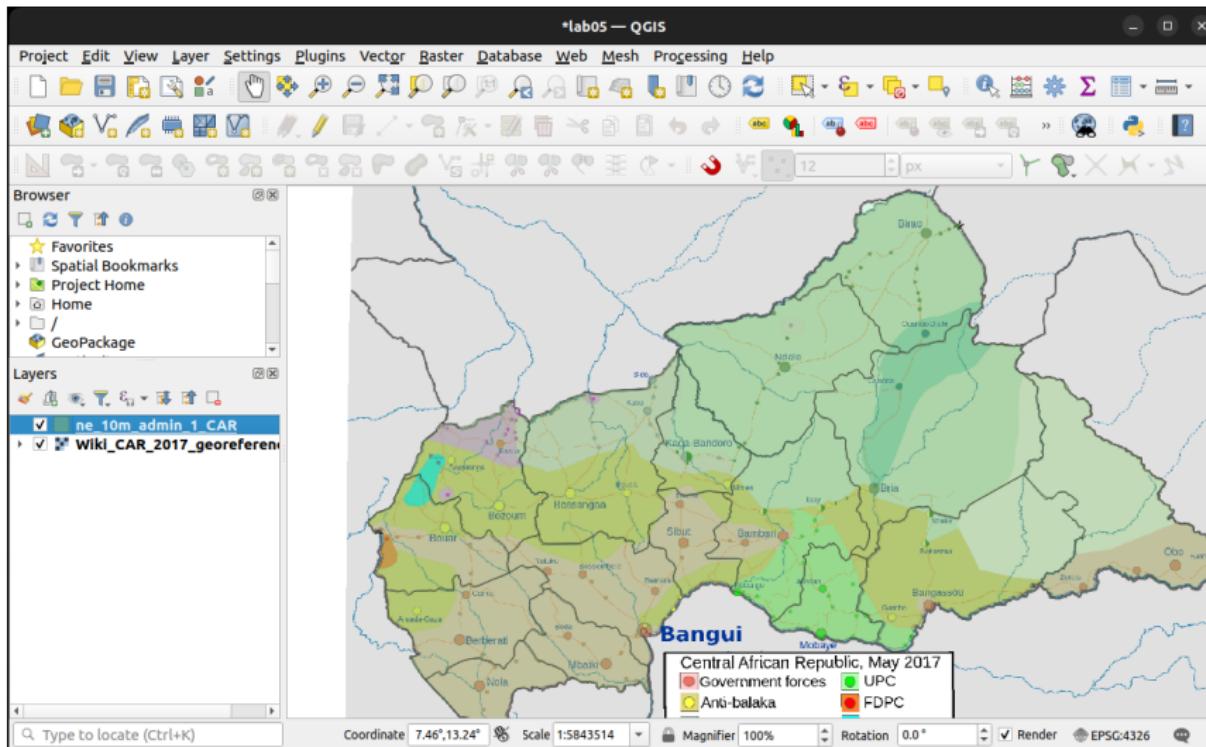
Before closing the Georeferencer window, let's *check the quality of fit*.
Back in the Project window, move the boundaries above the georeferenced raster in the Layers menu



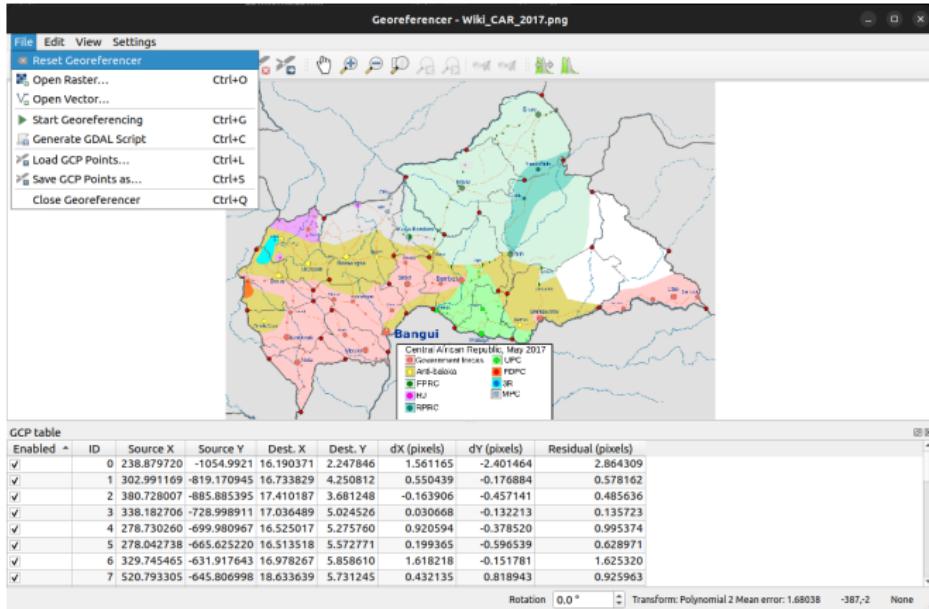
Let's make the countries layer semi-transparent. Double-click on the layer, go to Properties → Symbology. Set Opacity = 50



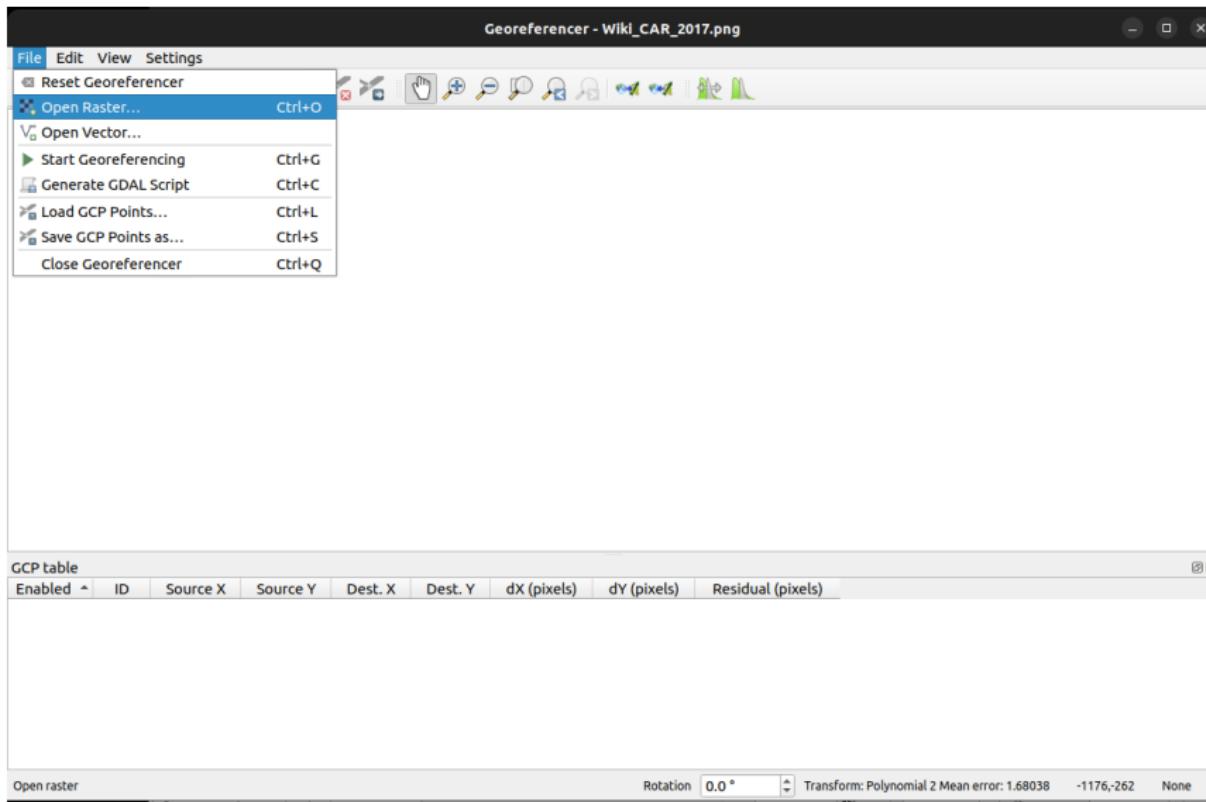
Check the quality of the fit. If you see any problematic mis-alignments, go back to Georeferencer, add more GCPs and run it again. The fit here seems ok...



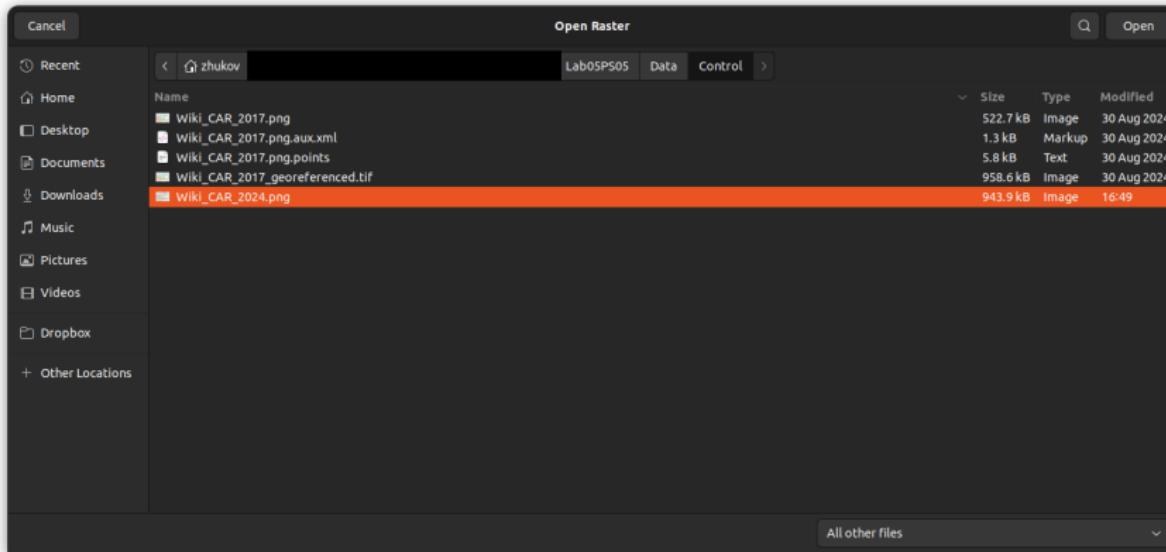
Let's now georeference the second map. To open a new Georeferencer window, go to **File → Reset Georeferencer** (or just open and re-launch the window)



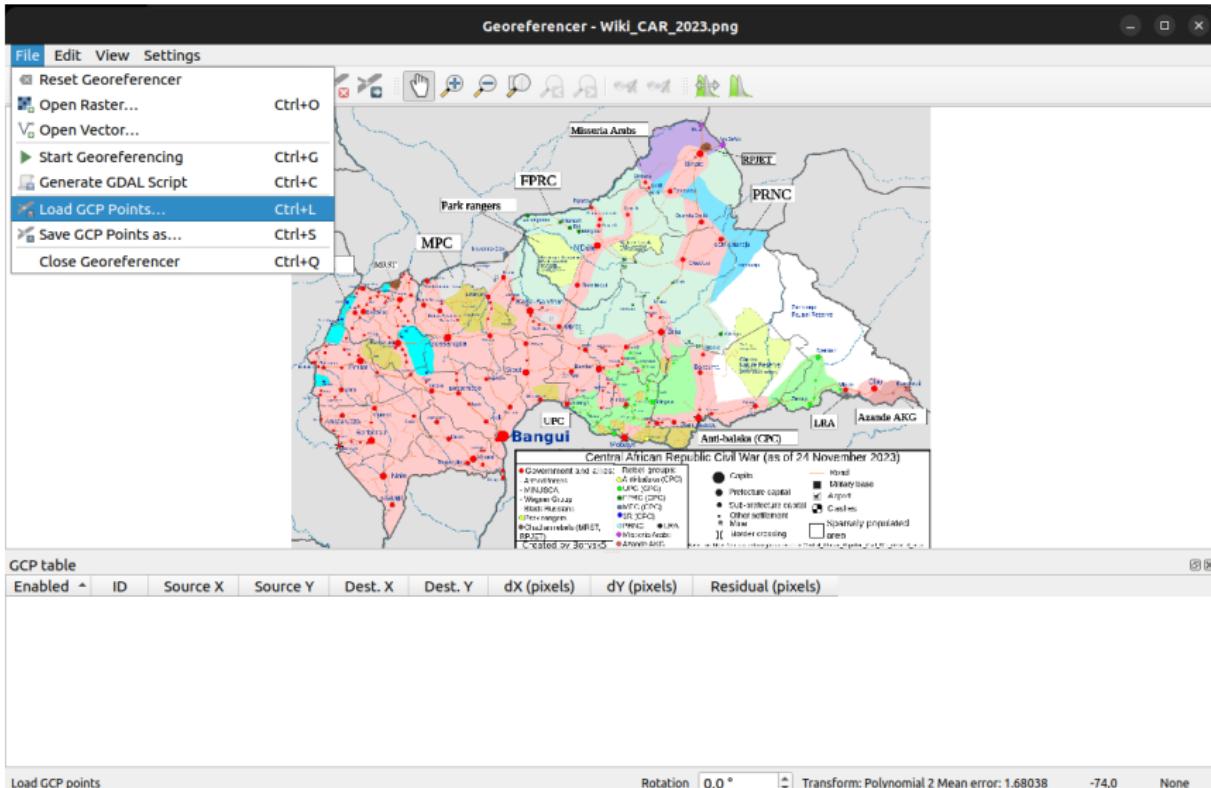
To open the other PNG image, go to File → Open Raster



Navigate to the Wiki_CAR_2024.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...



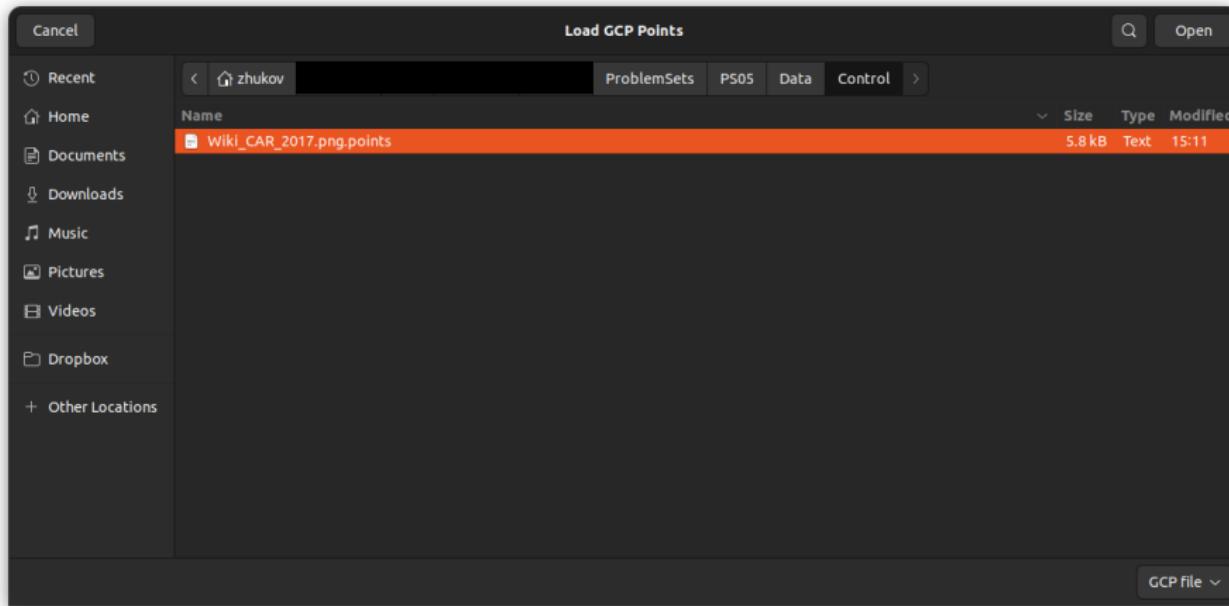
Load GCP points

Rotation 0.0° Transform: Polynomial 2 Mean error: 1.68038

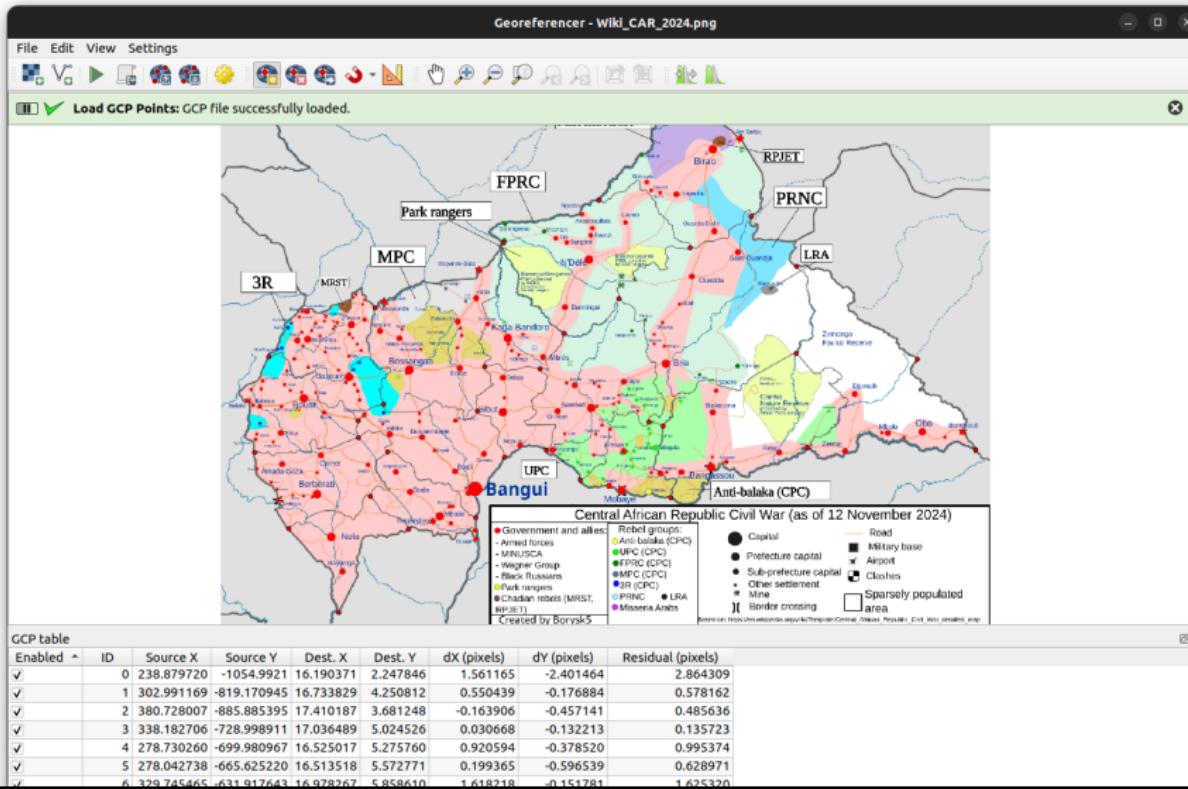
-74,0

None

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



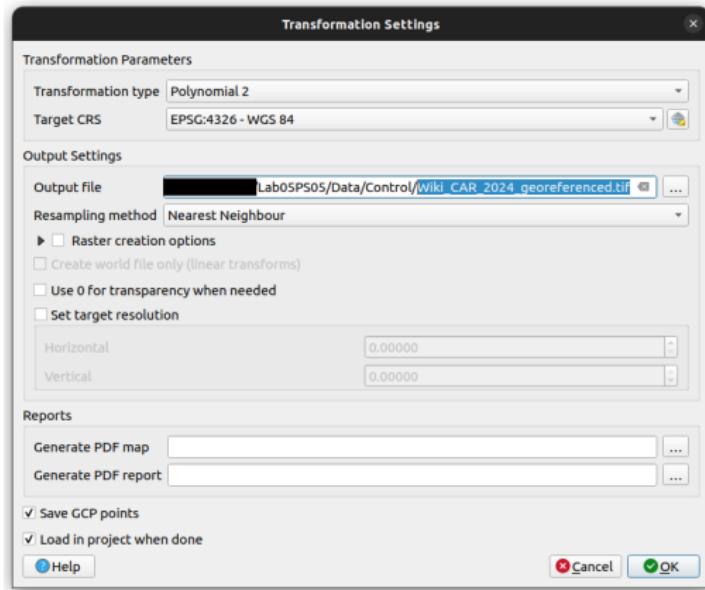
If the import was successful, you should see the same GCPs reappear in the Georeferencer window



Go to Settings menu →
Transformation settings

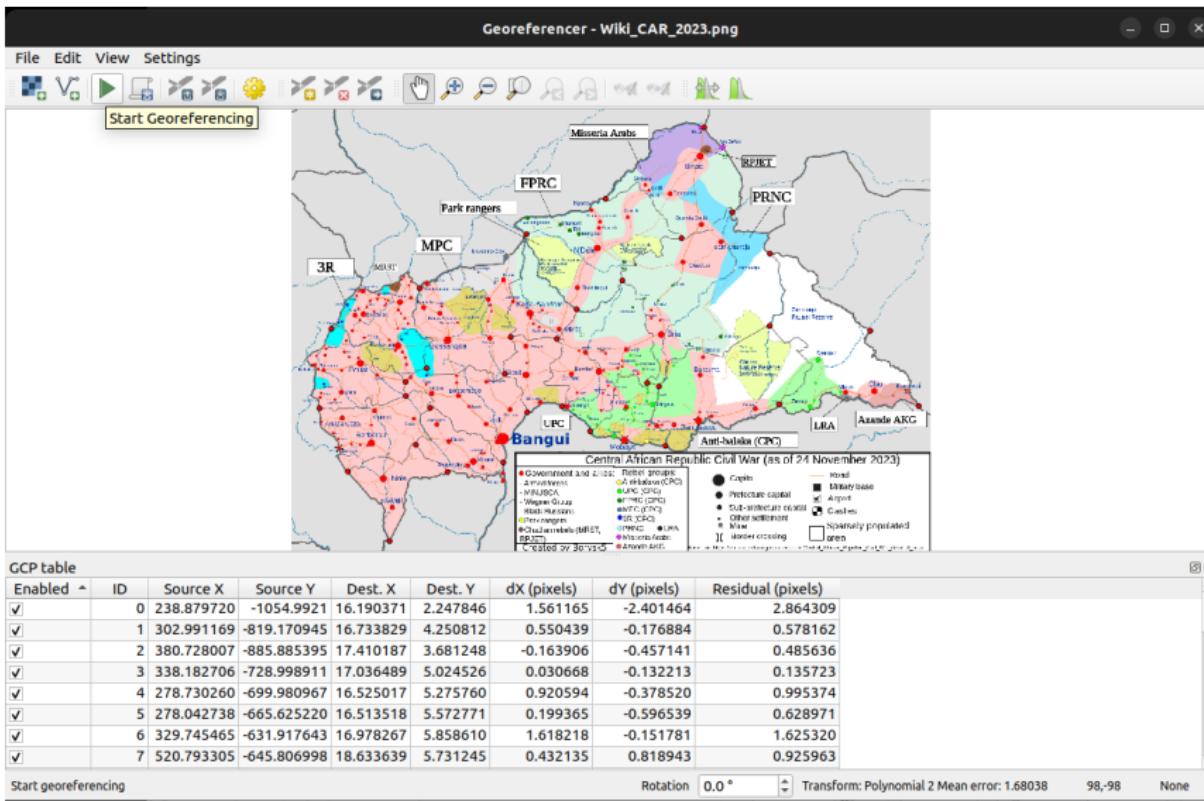
Set

- Transformation type = Polynomial 2
- Target CRS = EPSG:4326 – WGS 84
- Output file = select a folder, name the output file
Wiki_CAR_2024_georeferenced.tif
- Resampling method = Nearest neighbor
- Uncheck Set target resolution
- ✓ Save GCP points
- ✓ Load in QGIS when done

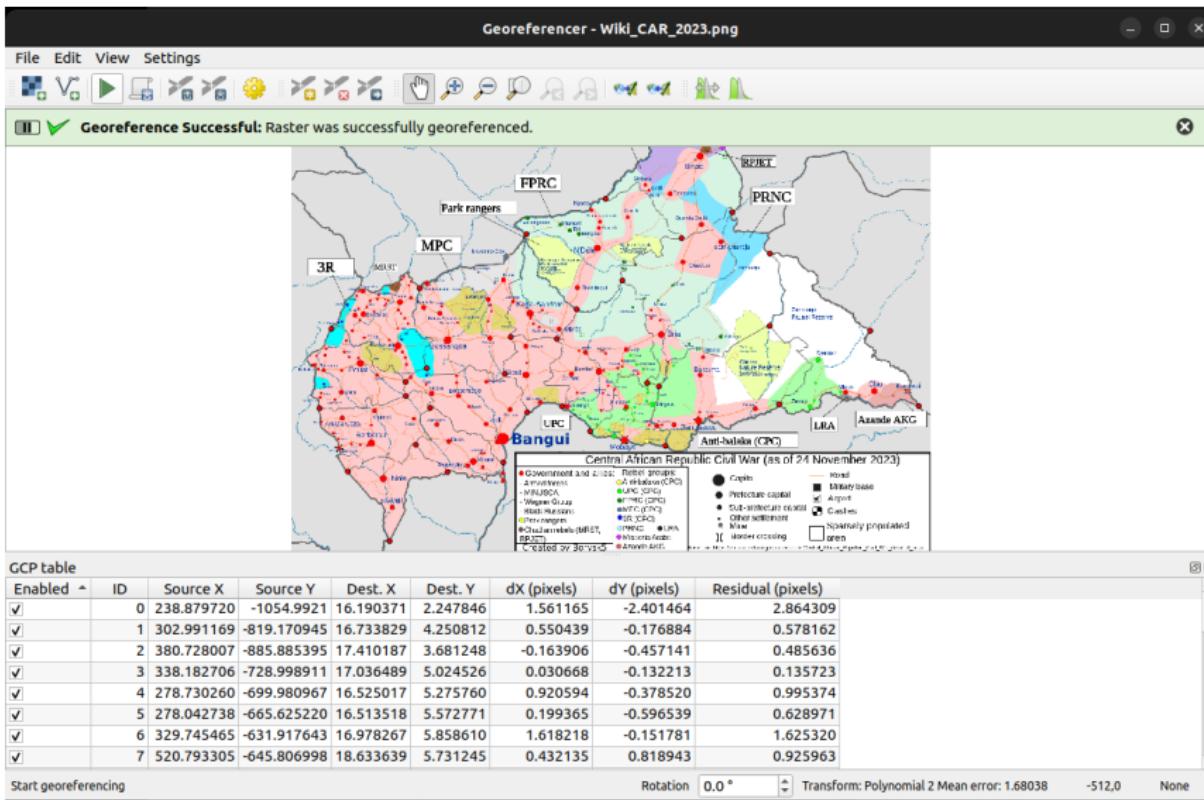


Click OK

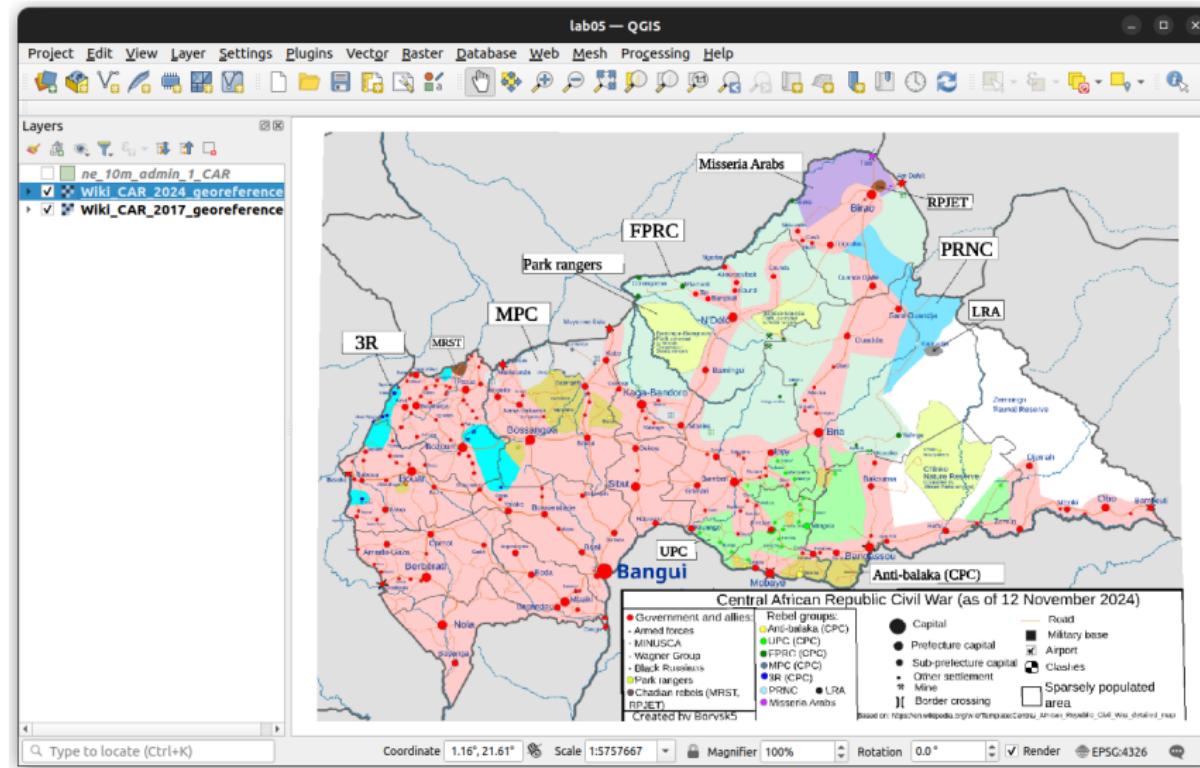
If everything looks fine, click on Start georeferencing (►) button



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

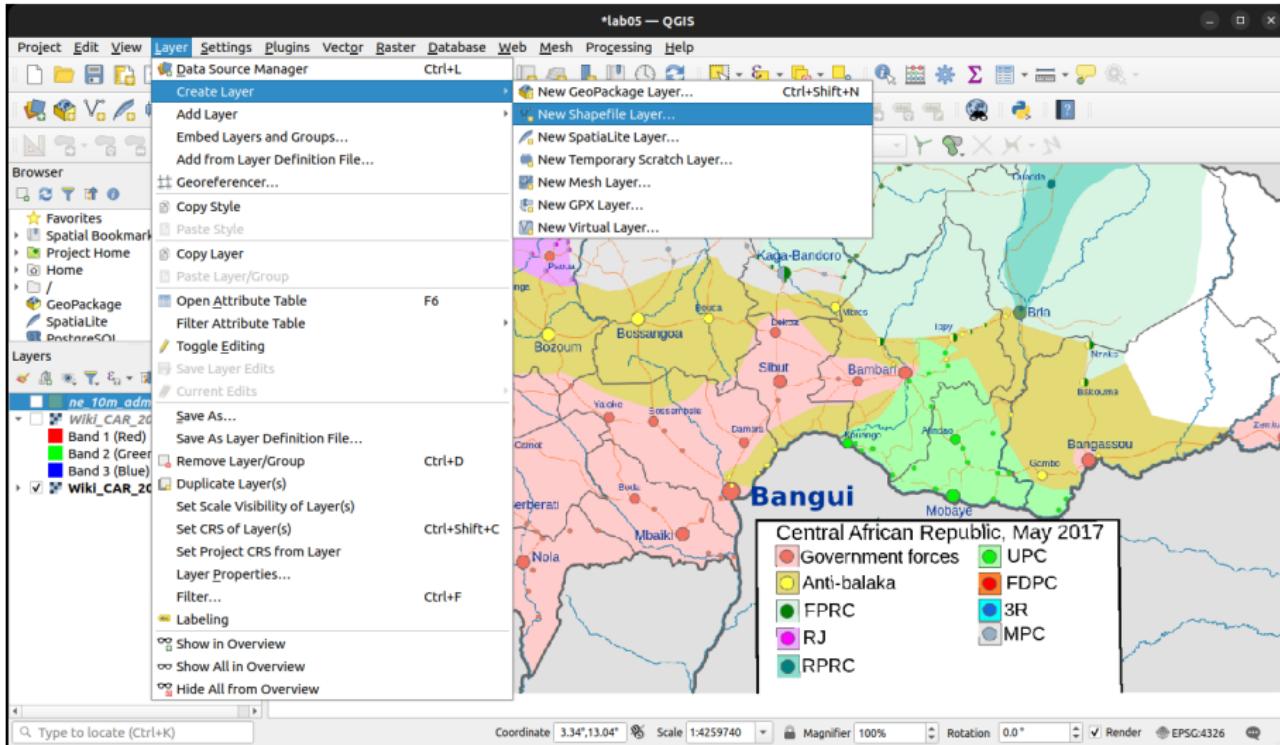


In the Project window, both georeferenced rasters should be in the Layers menu.
Now let's vectorize the raster (create polygons of government control)



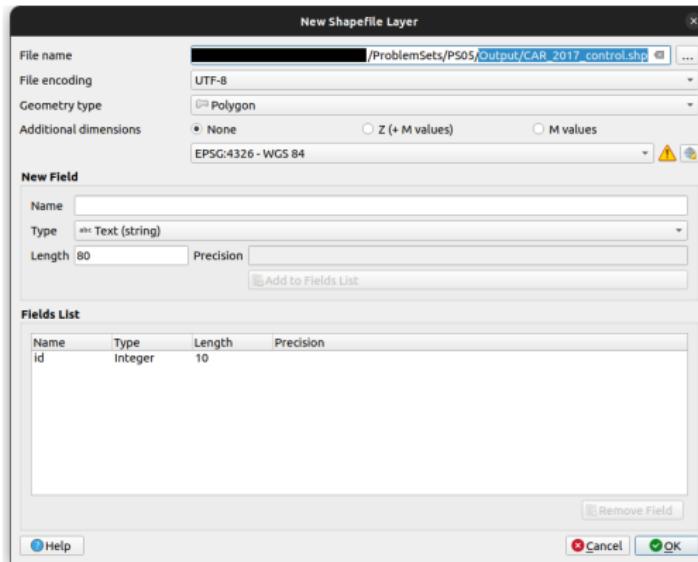
Vectorization

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



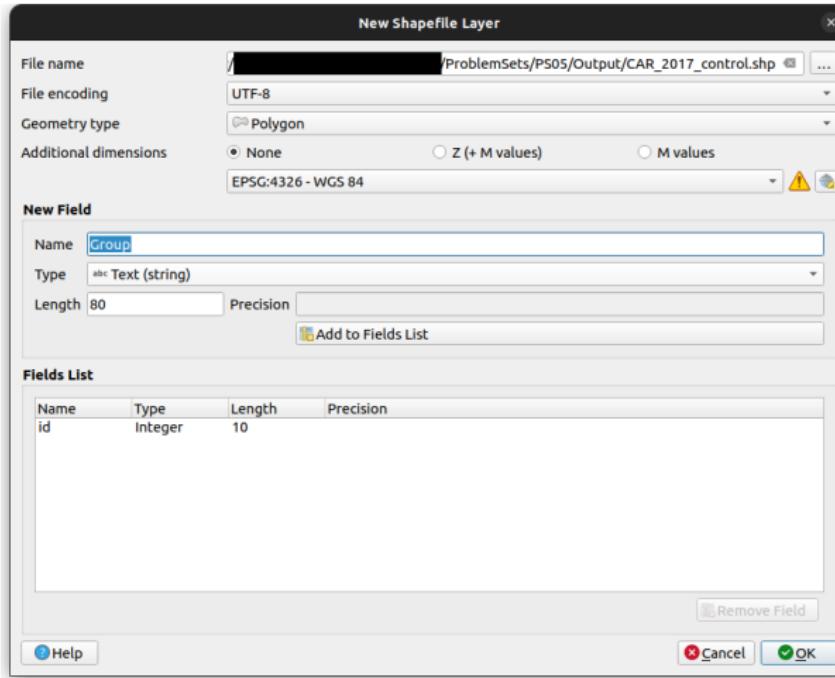
Set

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

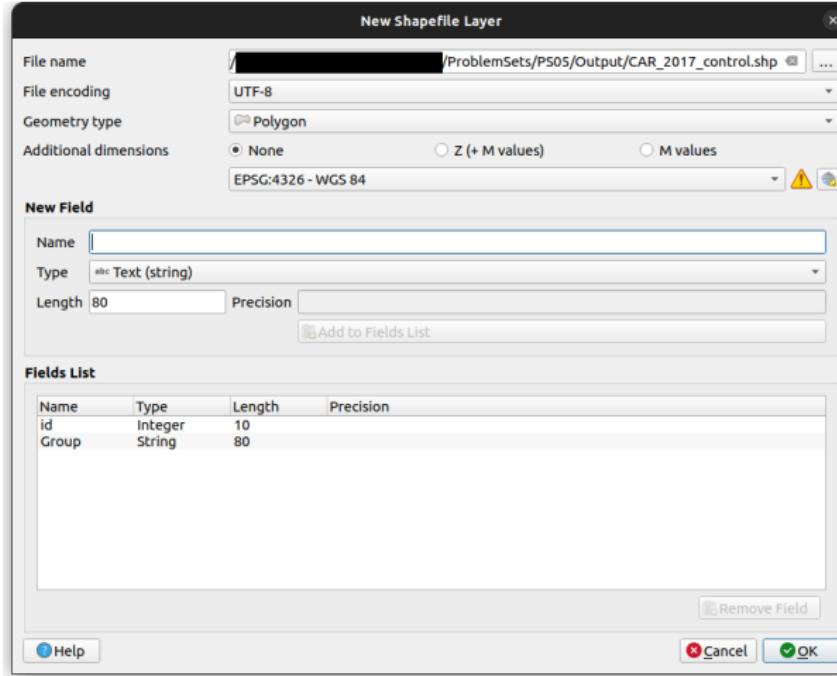


Let's add a new field to the attribute table:

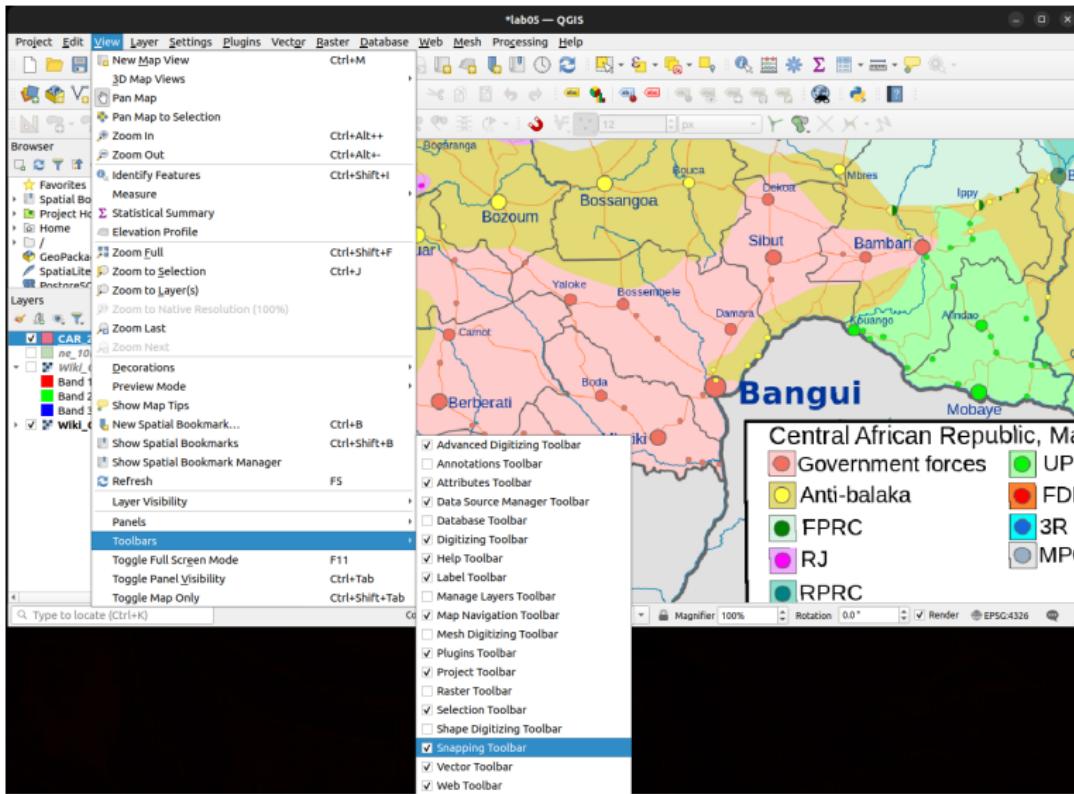
Name = Group, Type = Text. Click Add to Fields List



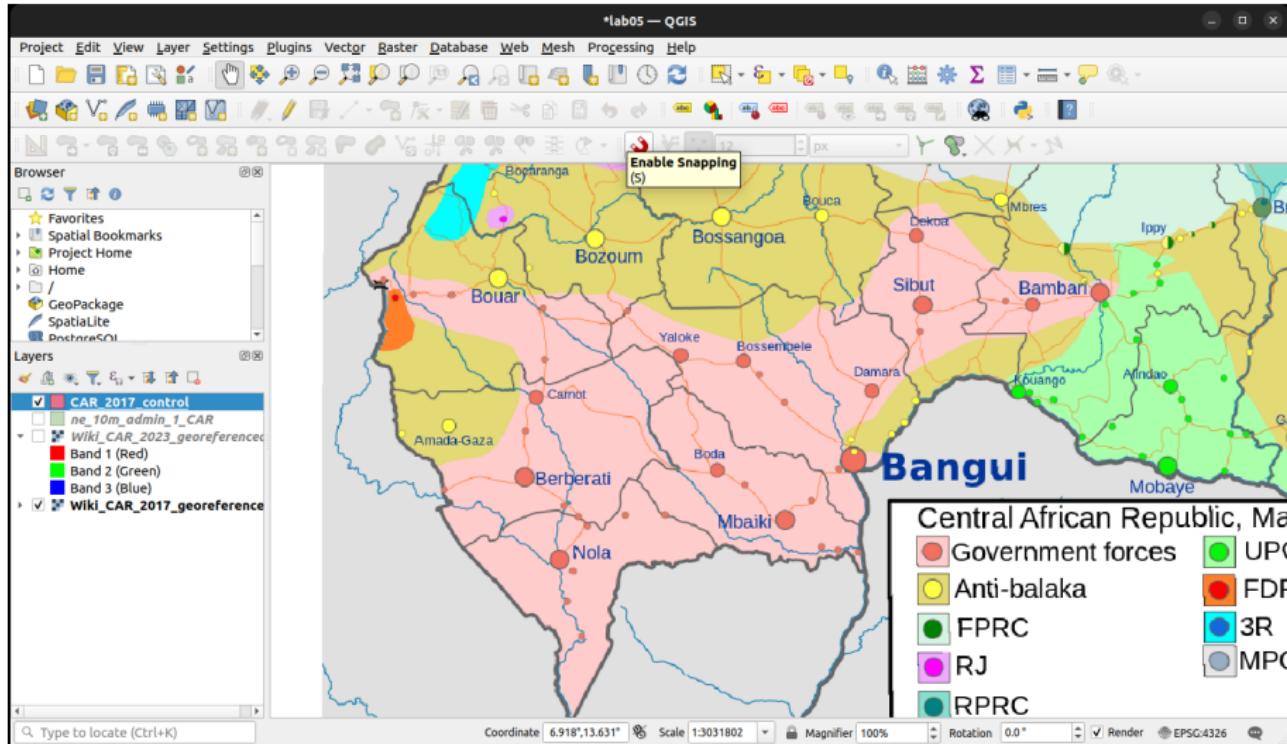
Click OK



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

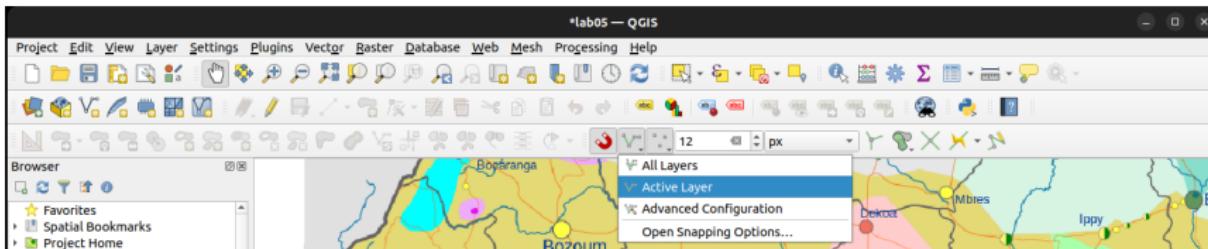


Click on the "Magnet button in the toolbar

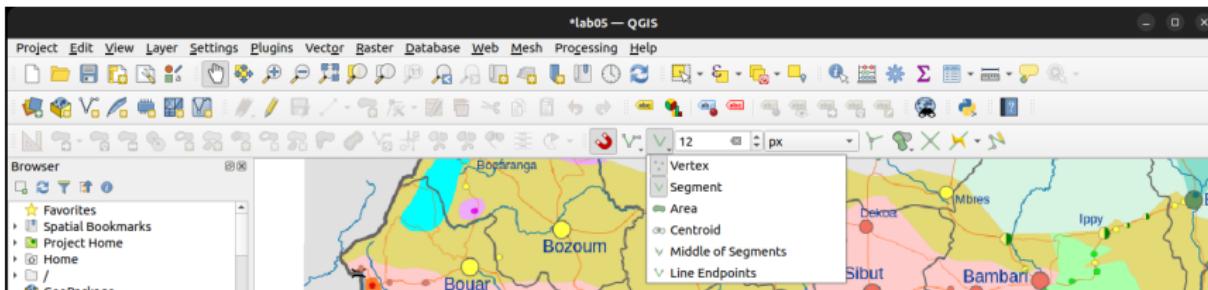


For the other Snapping toolbar buttons, set the following parameters:

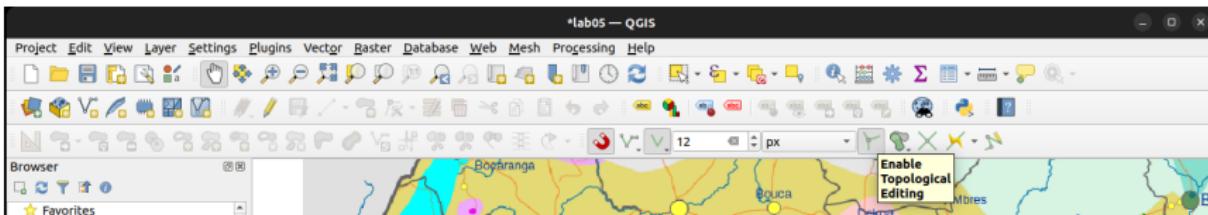
- ✓ Active Layer



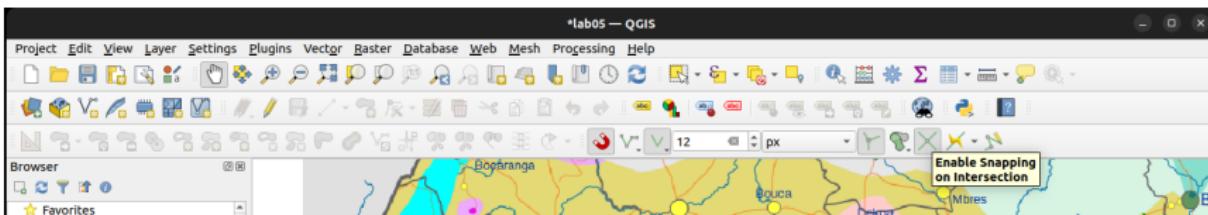
- ✓ Vertex
- ✓ Segment



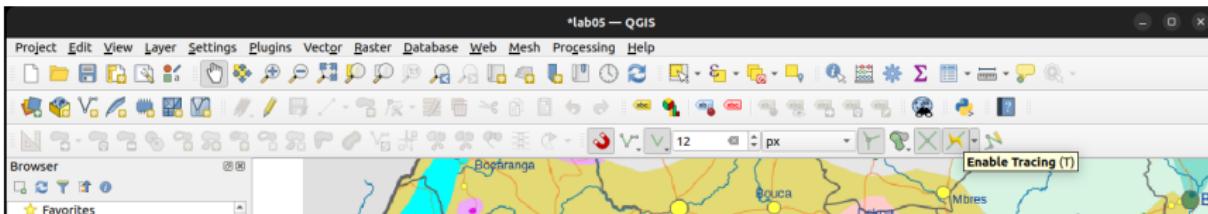
- ✓ Enable Topological Editing



- ✓ Enable Snapping on Intersection

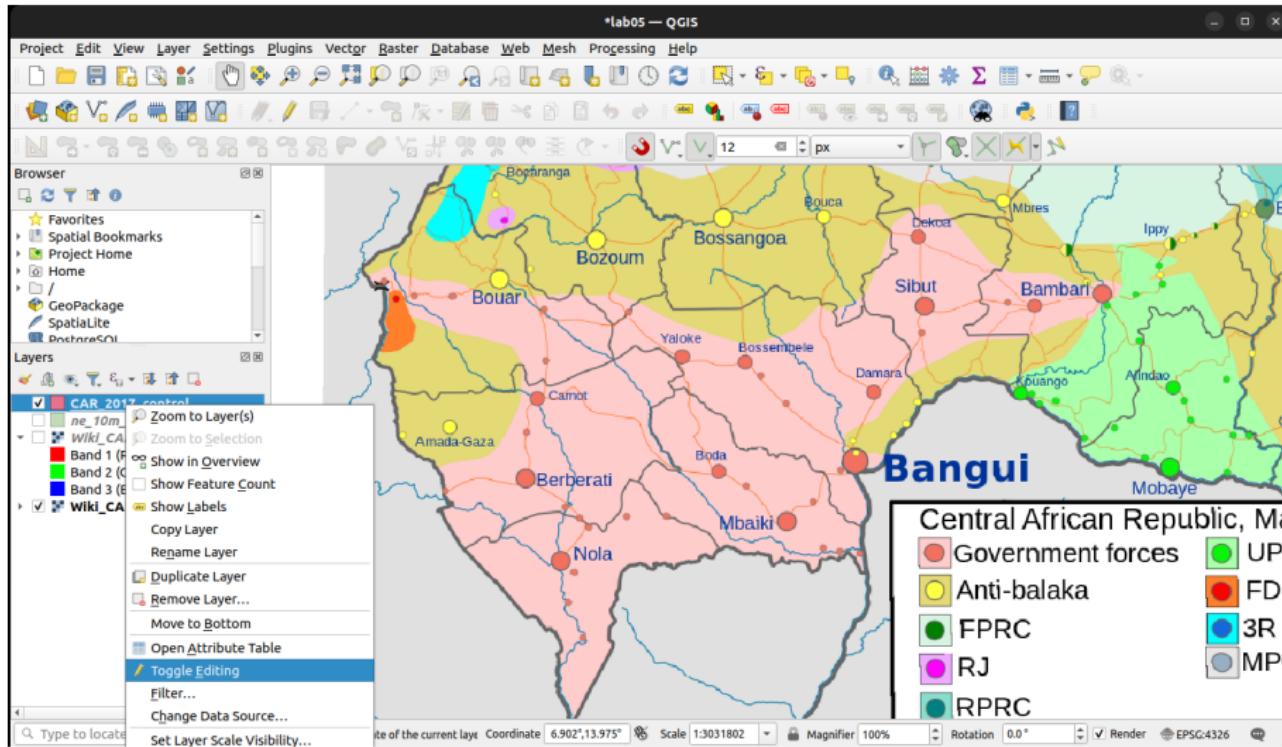


- ✓ Enable Tracing

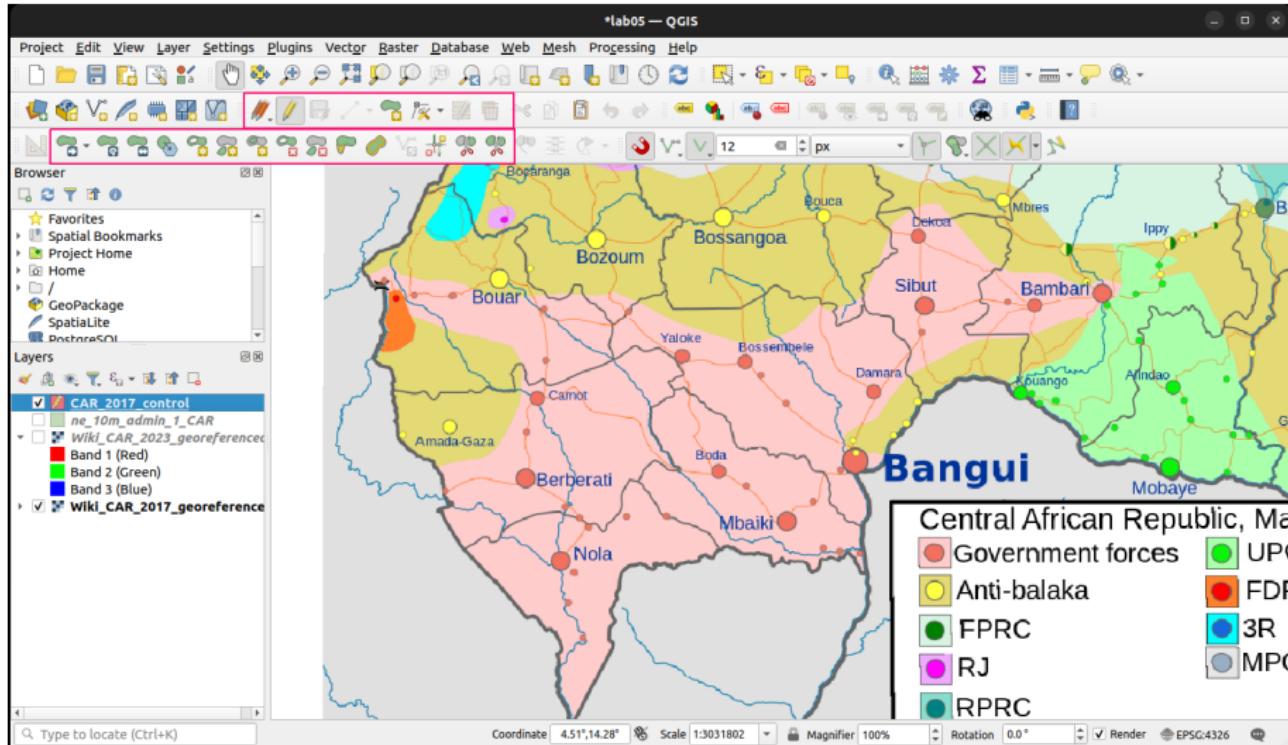


Let's go into *editing mode*.

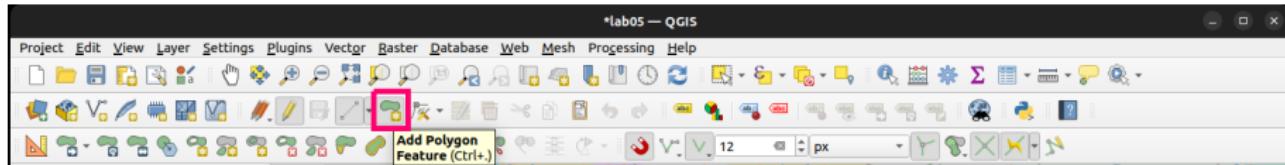
Right-click on CAR_2017_control in Layer menu → Toggle Editing



This will activate the Editing Toolbar



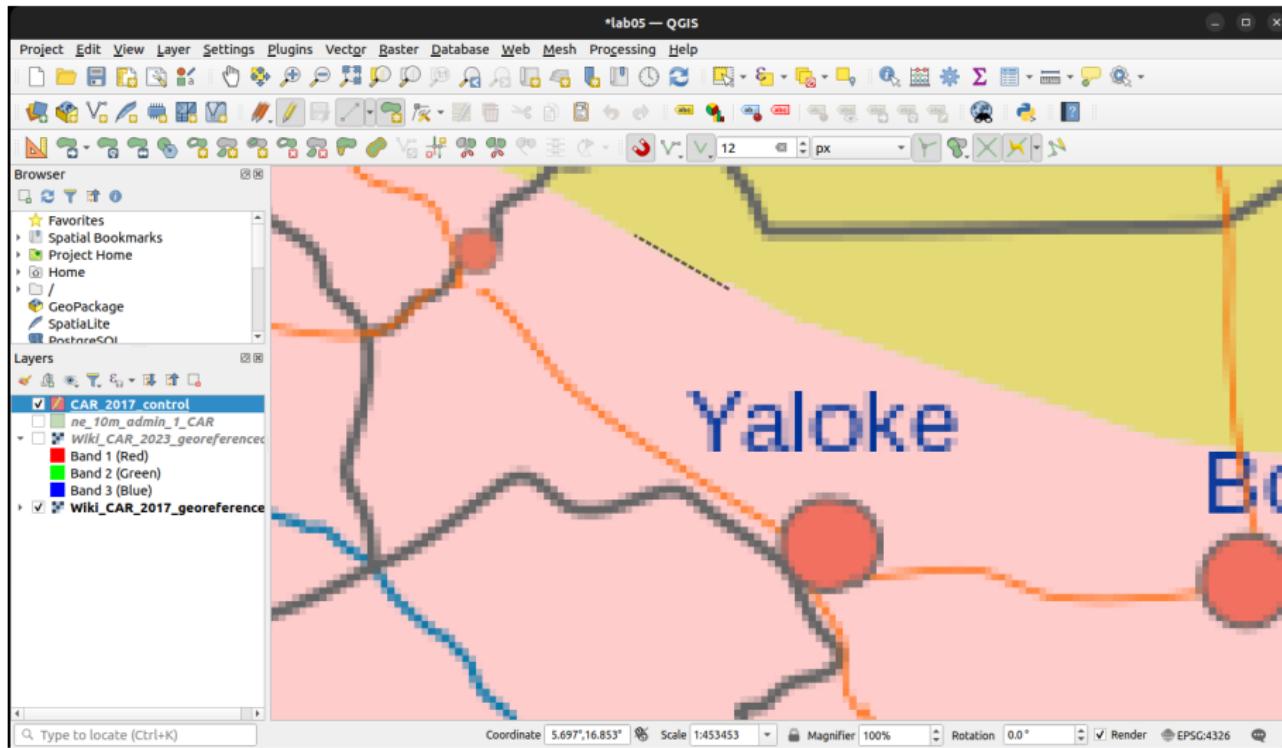
Click on the Add Polygon Feature icon (looks like a "blob" and a star, just to the right of the pencil, on the Editing Toolbar)



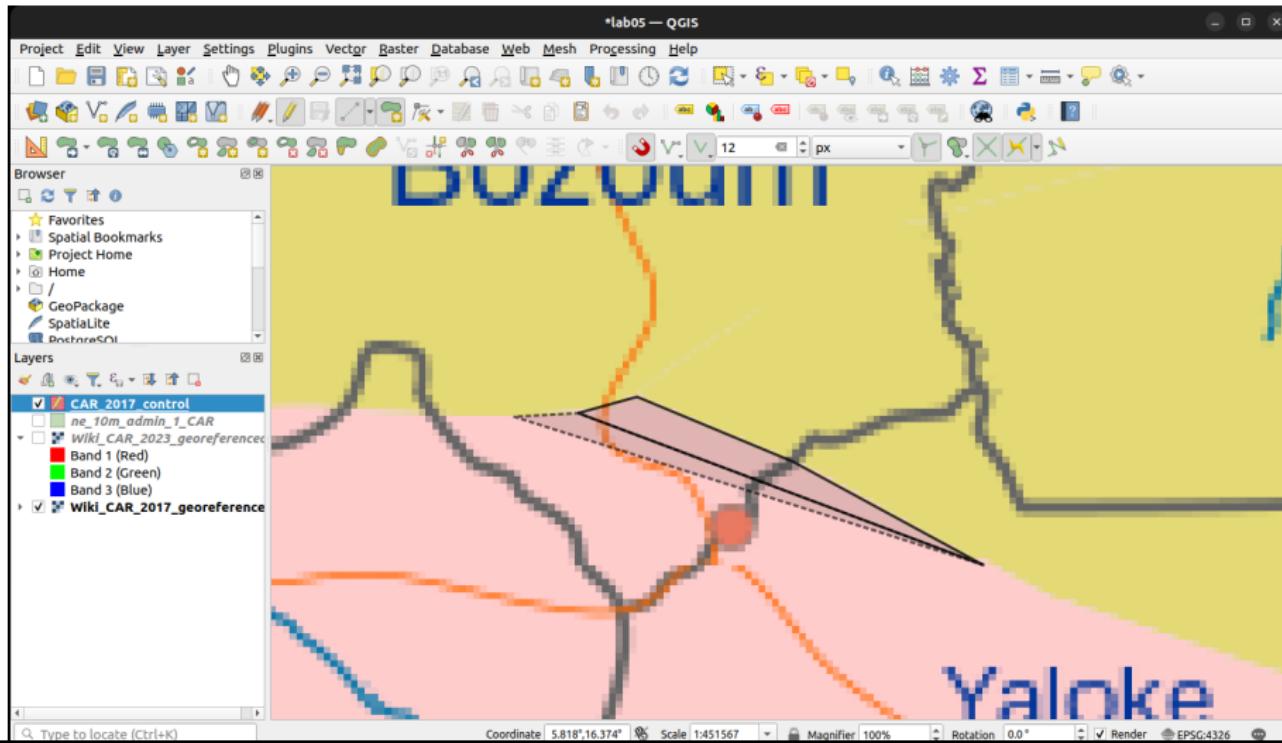
Tip: you may also want to *hide the inactive layers* while you vectorize. For example, you don't need (for now) the administrative boundary basemap (`ne_10m_admin_1_CAR`) or the 2024 raster (`Wiki_CAR_2024_georeferenced`). In the Layer menu, uncheck the boxes next to everything other than `CAR_2017_control` and `Wiki_CAR_2017_georeferenced`



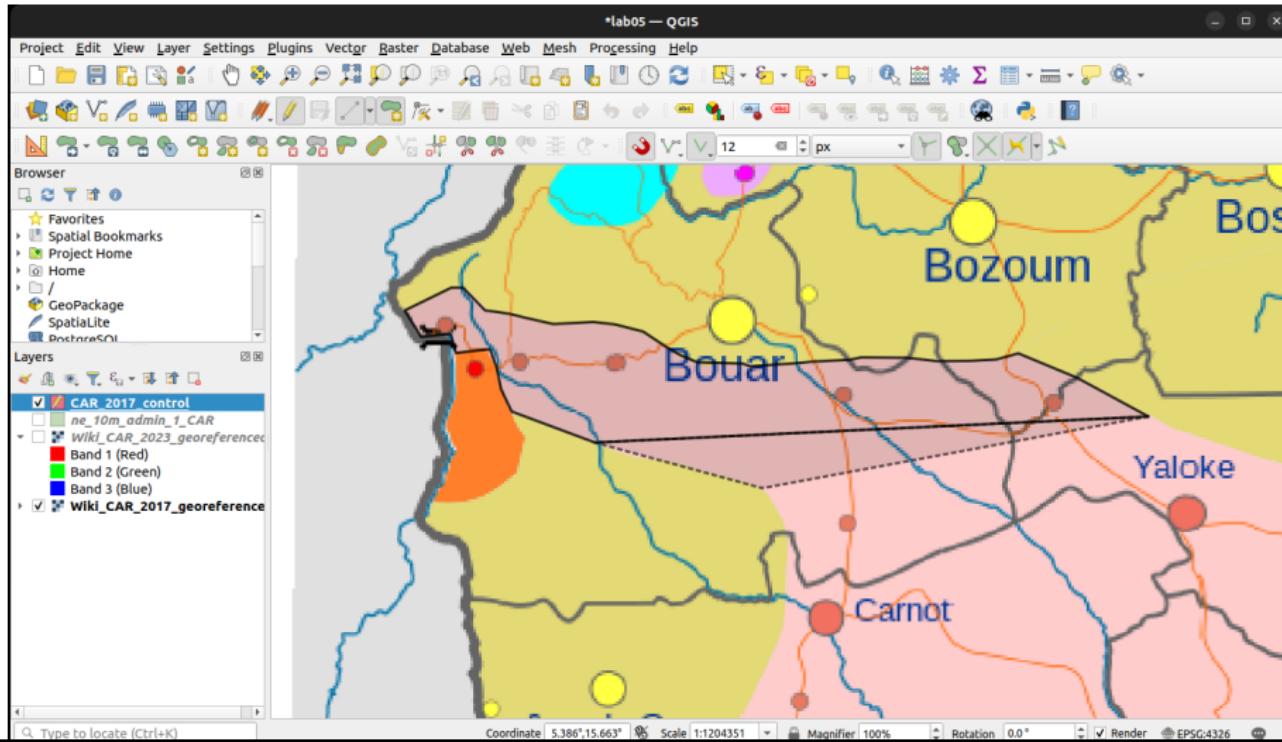
Make sure CAR_2017_control is highlighted in the Layer menu. Start tracing the pink area (representing government control) by left-clicking on its boundary



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



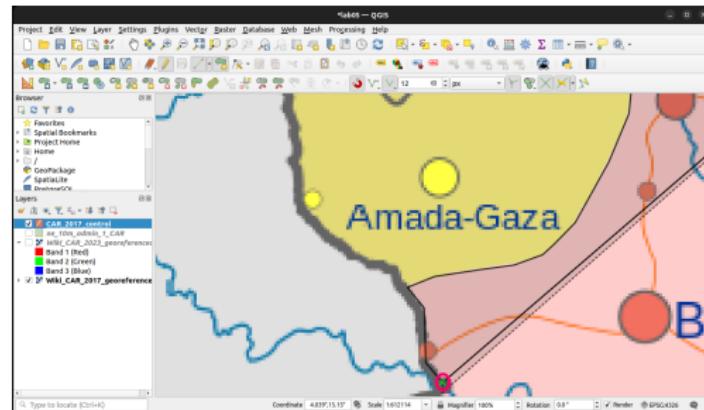
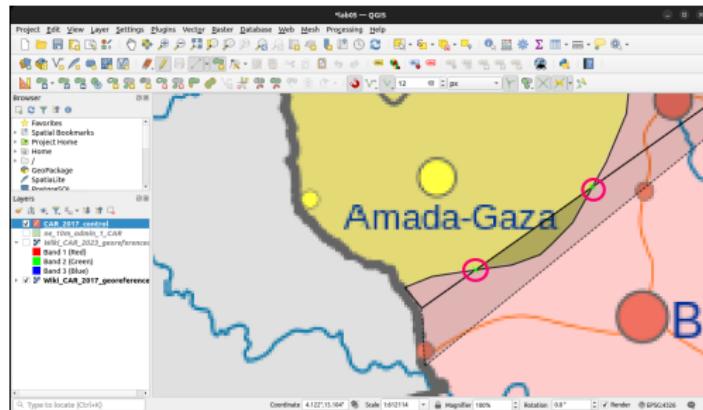
Each left-click ends one straight-line segment and begins another (make sure you add enough segments to capture the curvature of the border). As you keep adding vertices, the polygon will gradually take shape



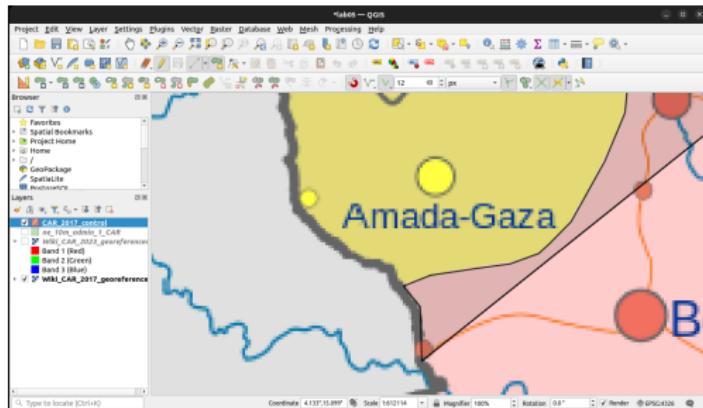
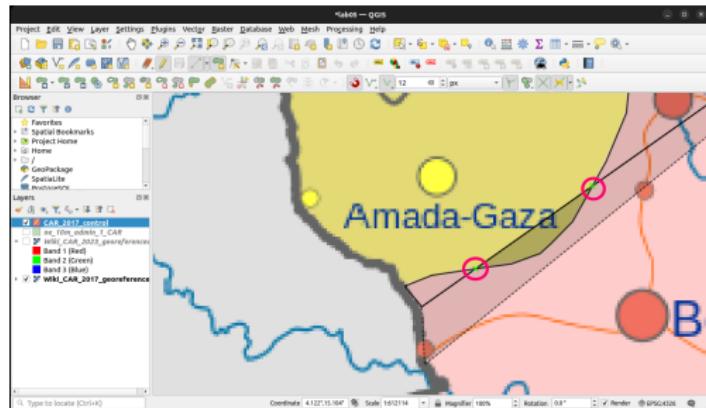
Every once in a while, you'll see green x's appear while creating a new feature. This typically means one of two things:

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

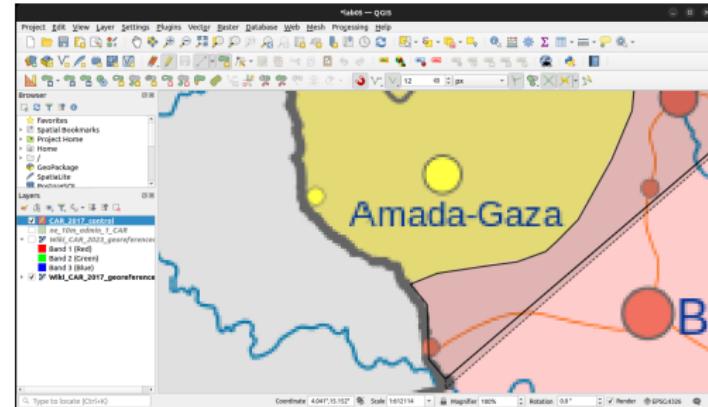
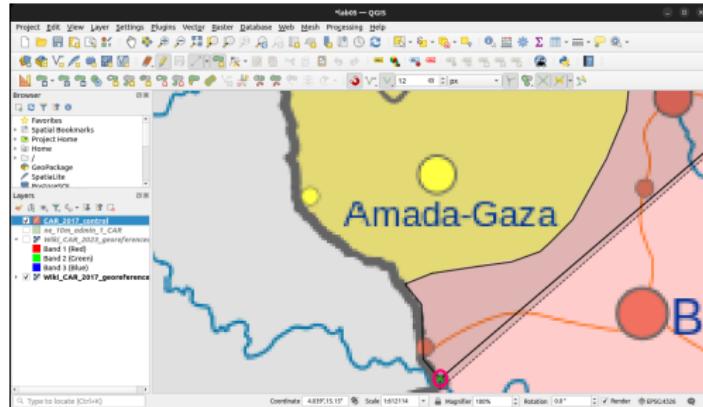
These are both considered geometry errors, and should be avoided.



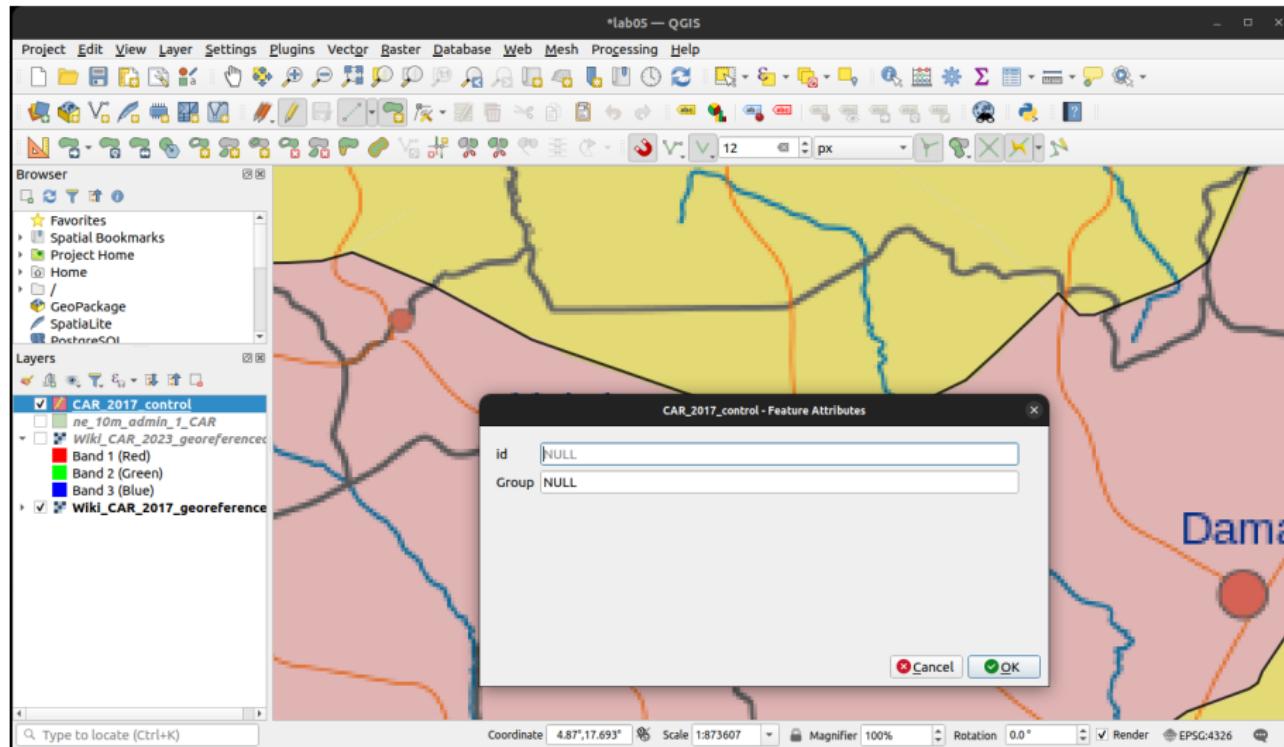
Sometimes (but not always), *self-intersections* “untangle” themselves as you add more vertices and refine the shape of the polygon:



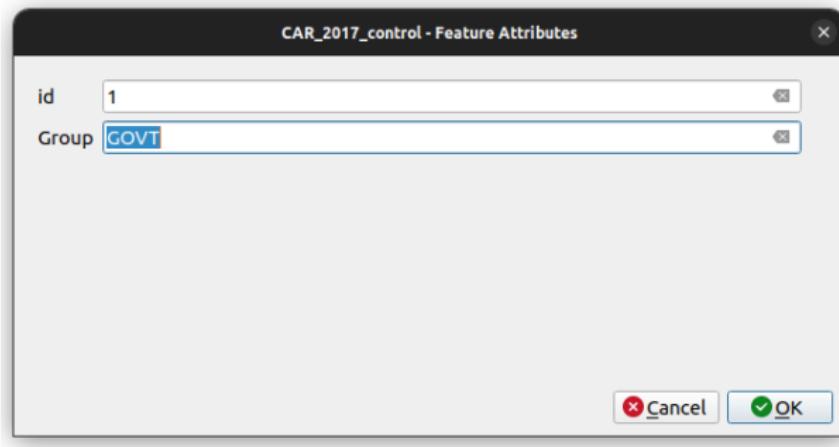
With *duplicate vertices*, you'll need to go back to get rid of the double point (by clicking delete/backspace)



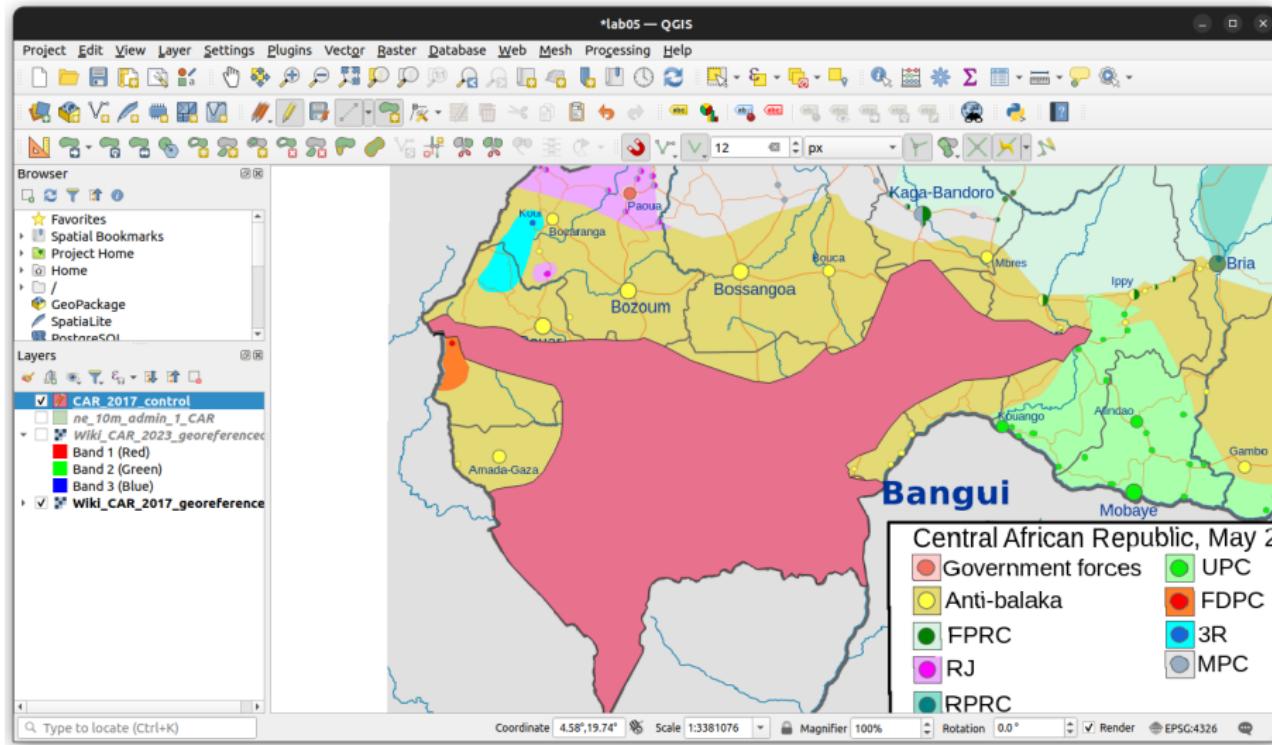
As you approach the end of the loop, right-click to add the feature. You'll be prompted to fill out the field information



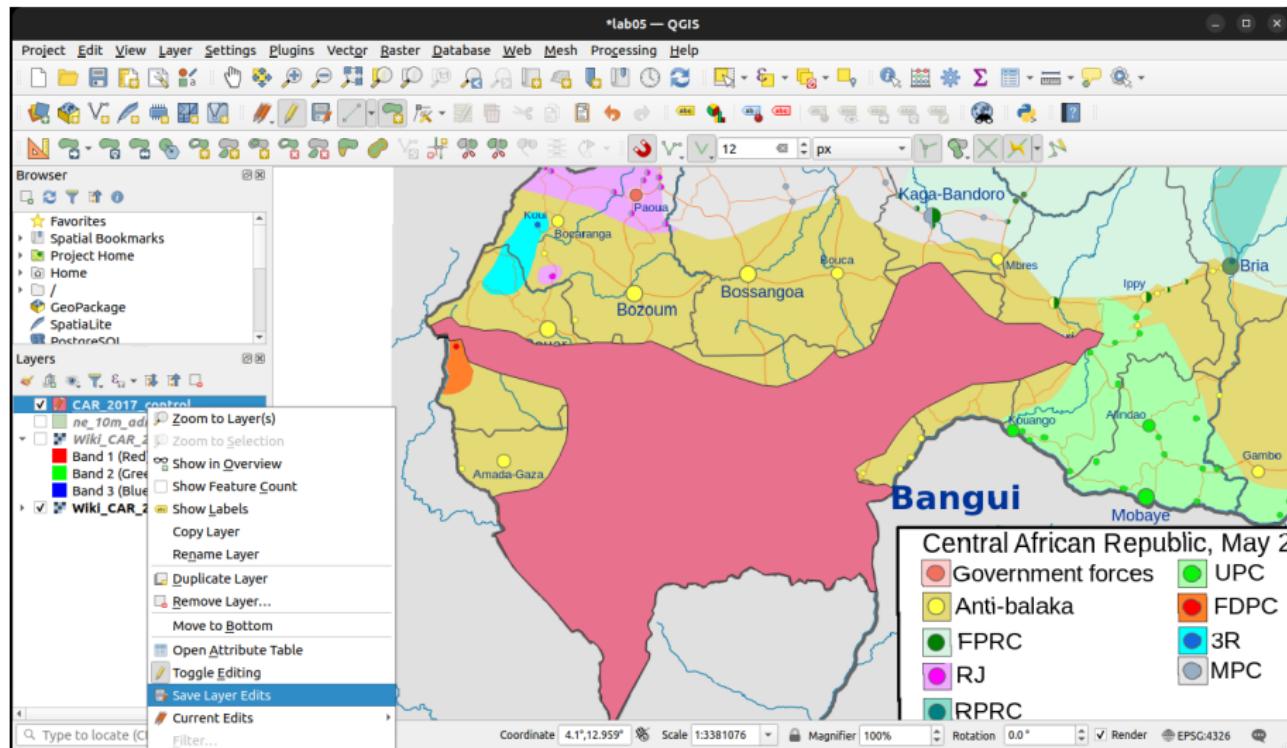
For the id field, enter the number of the polygon (e.g. "1" if it's the first one you created). For Group, enter GOVT.



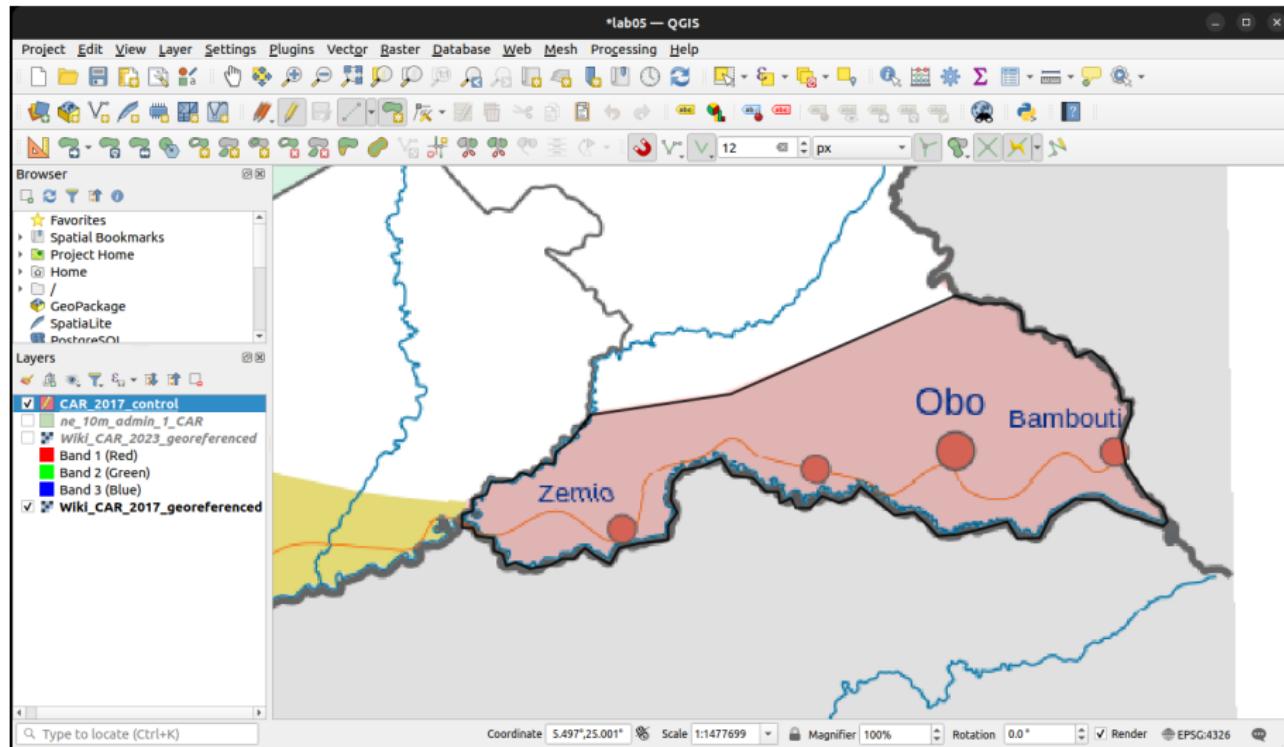
The new feature should appear on the map



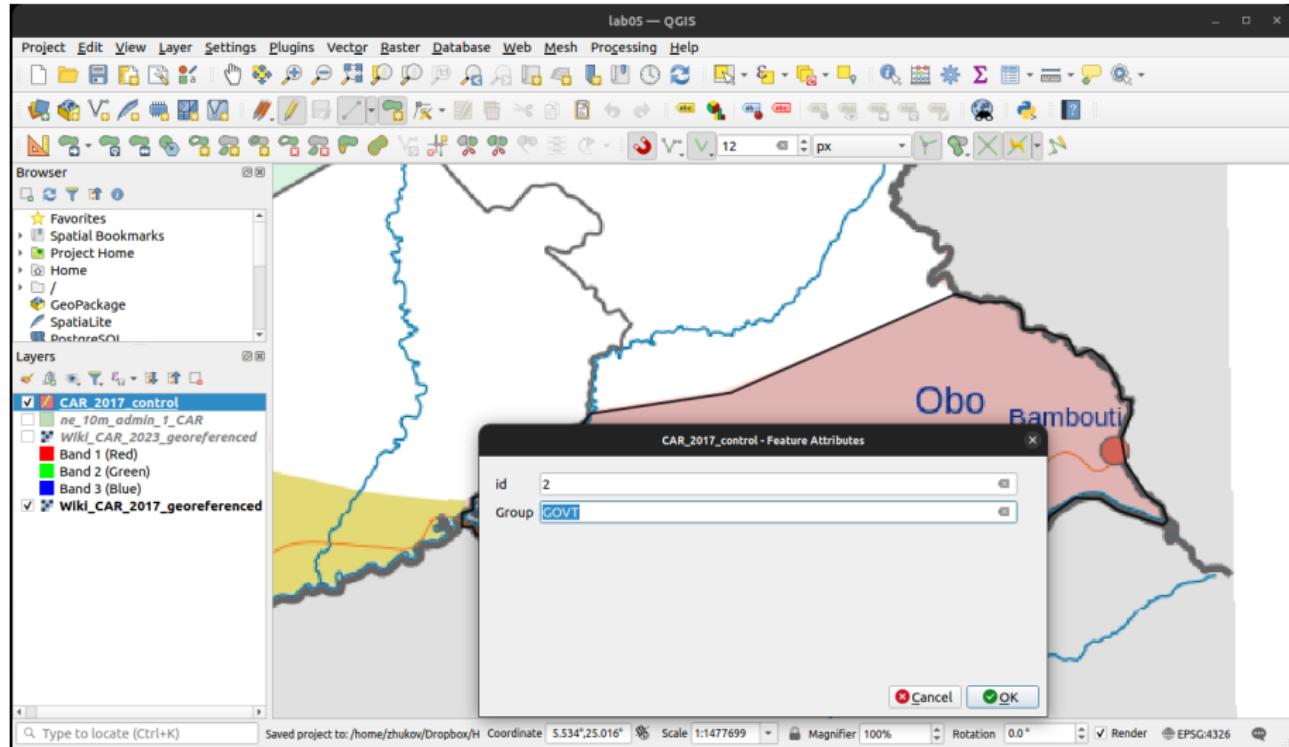
Save your progress by right-clicking on CAR_2017_control in the Layer menu, and selecting Save Layer Edits.



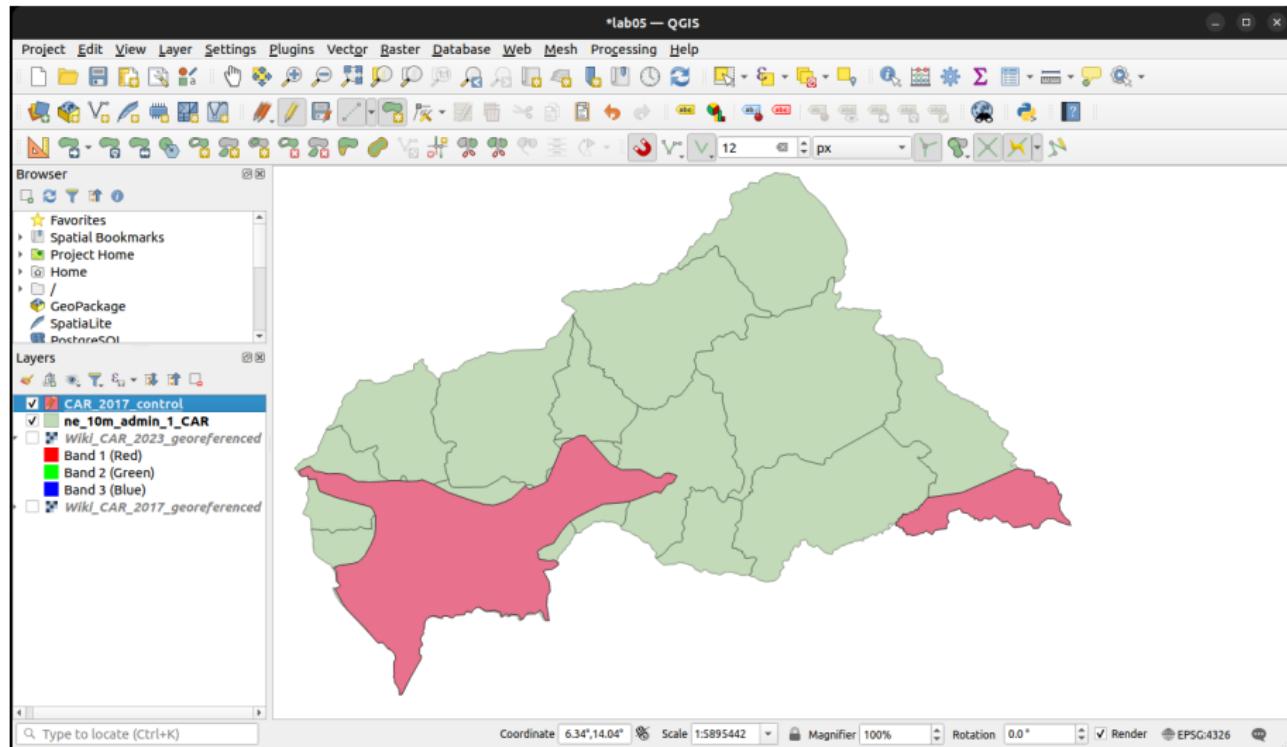
Repeat the same steps for the other government-controlled area in the east of the country (there should be two such polygons total in the 2017 map)



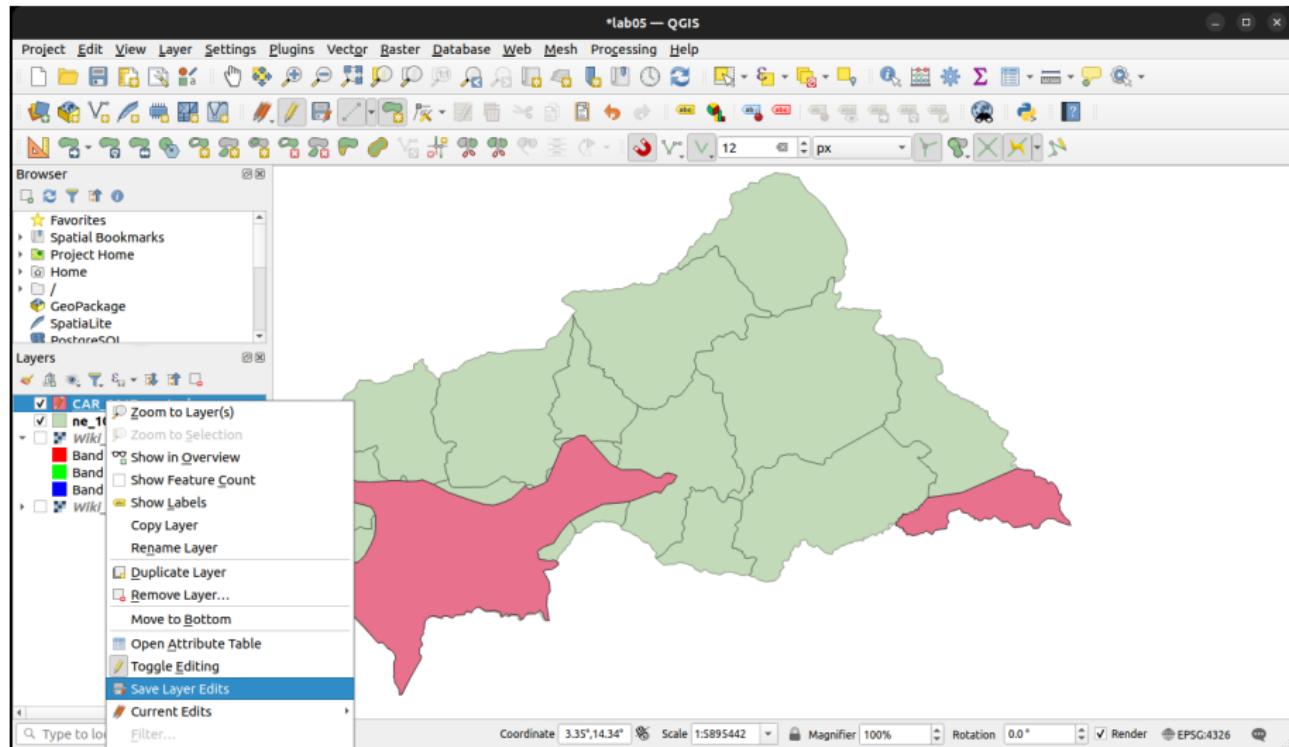
The attributes here should be id = 2 and Group = GOVT



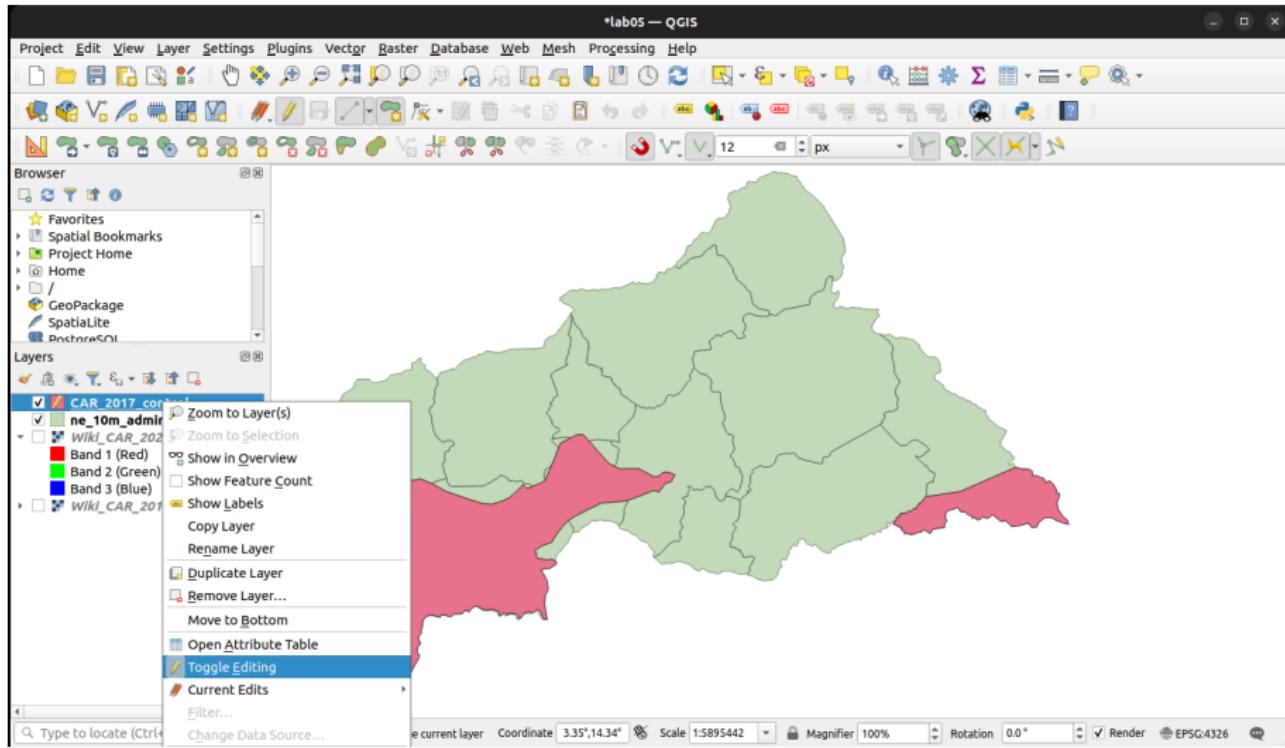
Here's how the vectorized polygons should look when you're done (reactivating the `ne_10m_admin_1_CAR` layer for context)



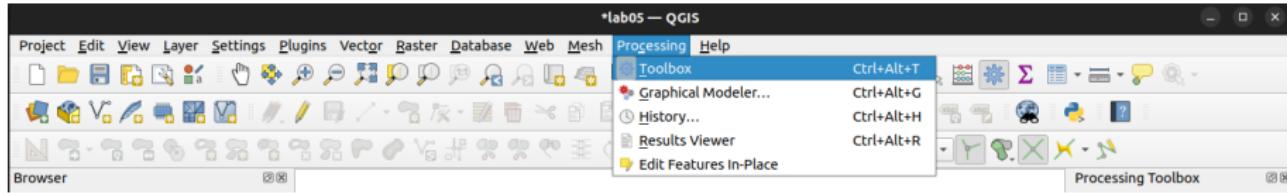
Save your progress (again) by right-clicking on CAR_2017_control in the Layer menu, and selecting Save Layer Edits.



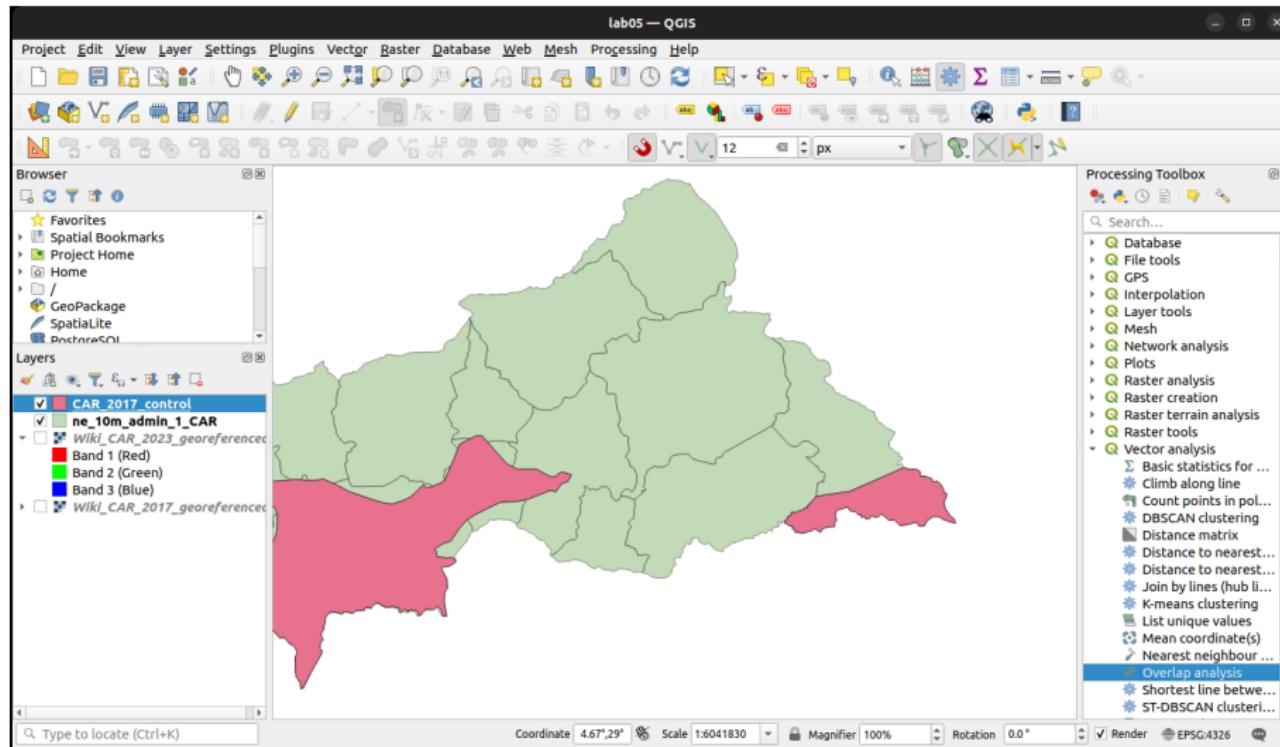
Turn off editing mode by right-clicking on CAR_2017_control in the Layer menu, and de-selecting Toggle Editing.



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

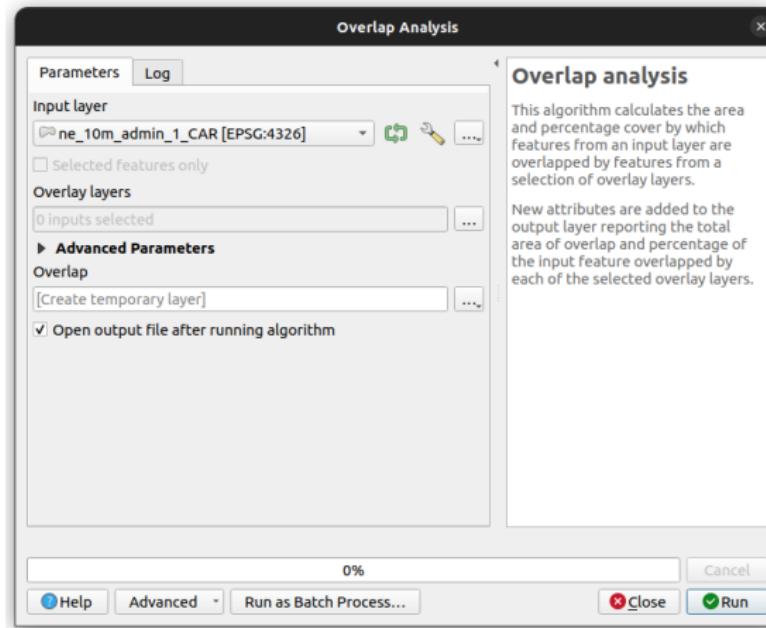


In the Processing Toolbox in the right, double-click on Overlap analysis in the Vector analysis sub-menu



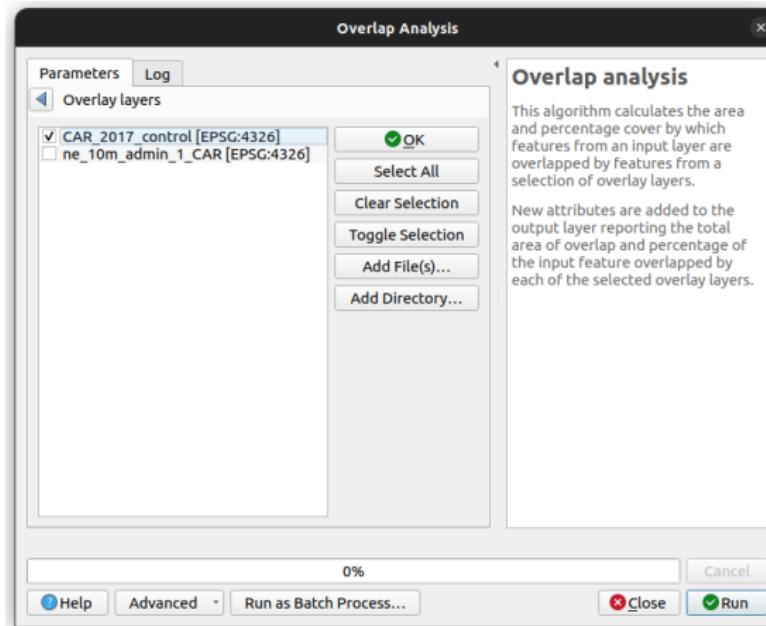
In the Overlap Analysis window, set

- Input layer = ne_10m_admin_1_CAR



Set

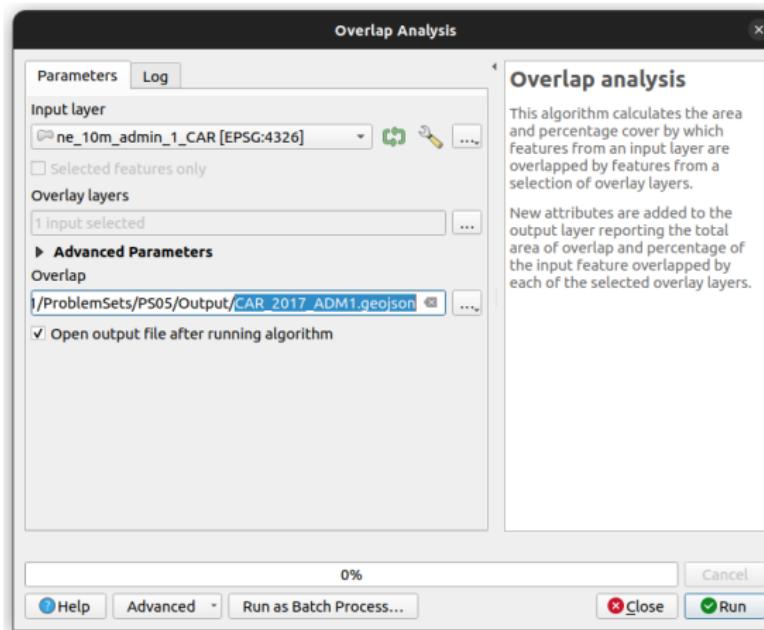
- Overlay layers = CAR_2017_control



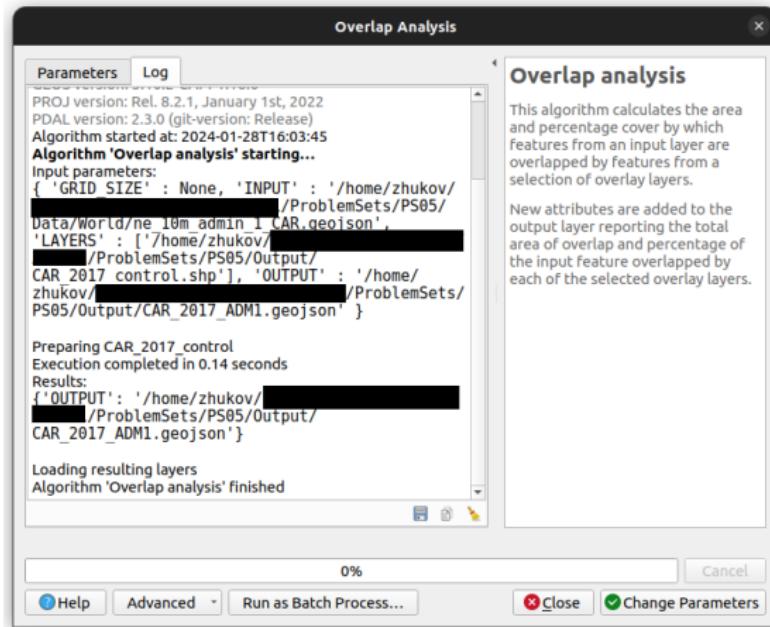
Set

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

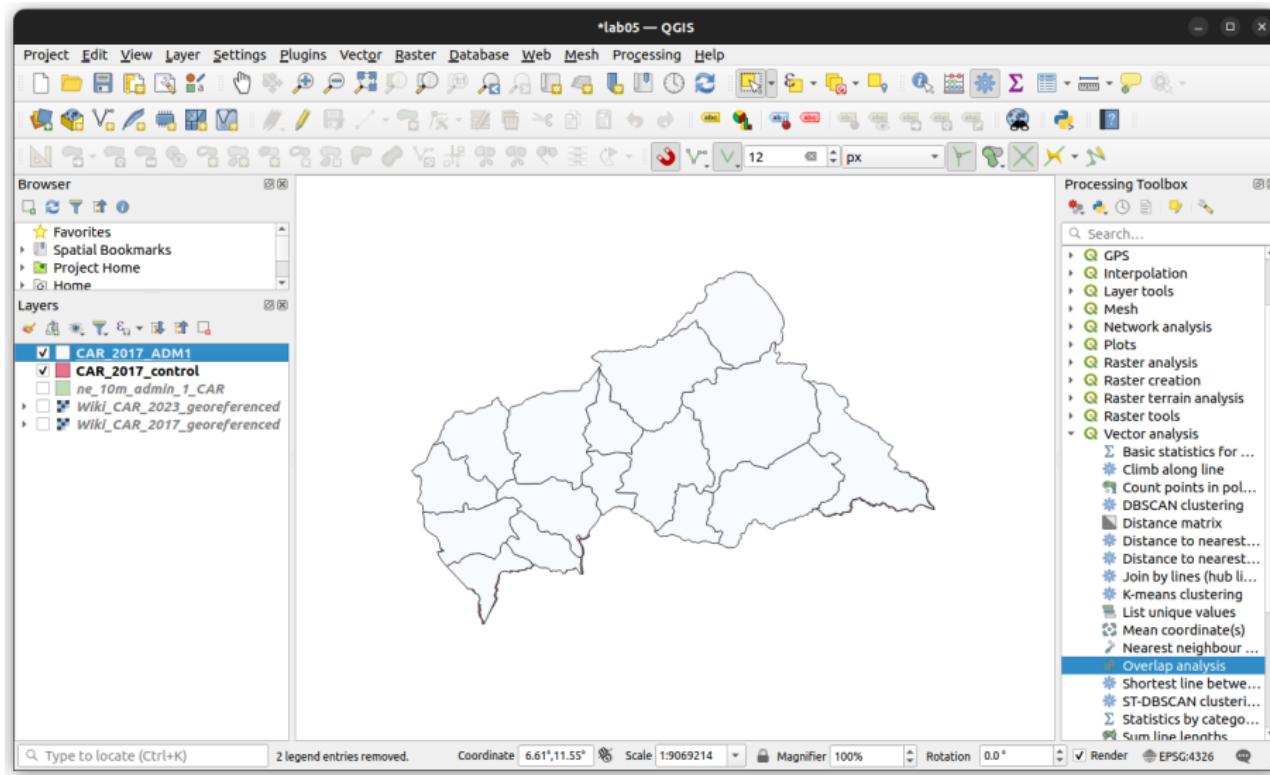
Click Run



Check the log to make sure there were no errors

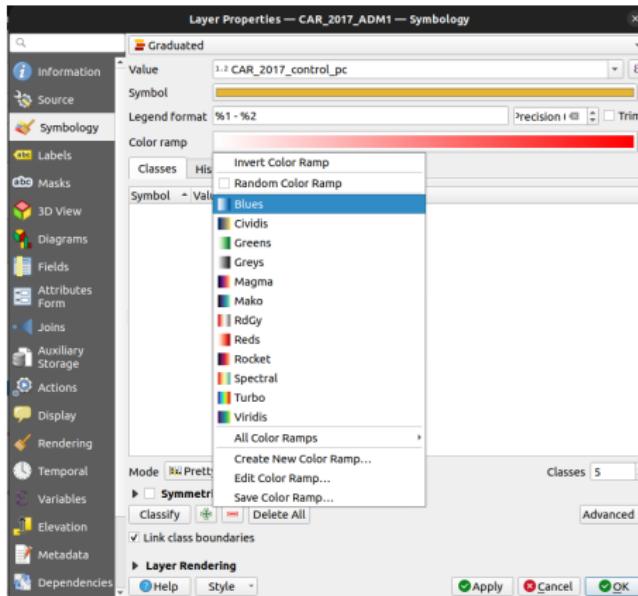


A new layer CAR_2017_ADMIN1 should appear in the map and Layer menu.
Double-click on it to open up its Properties



Set

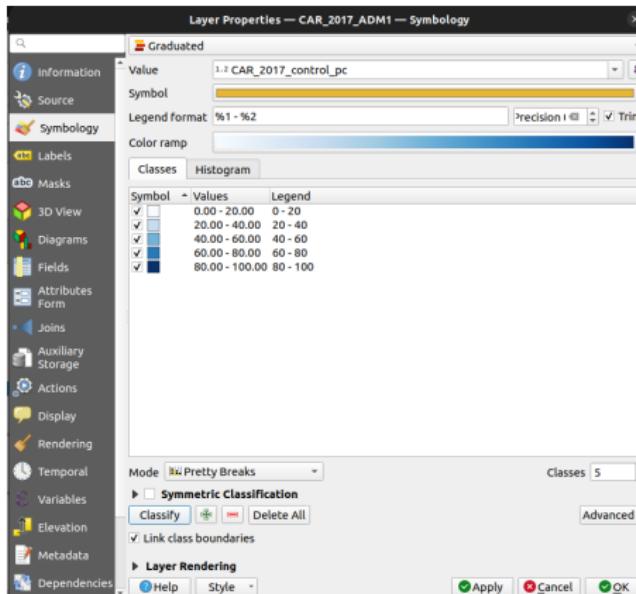
- Symbology type = Graduated
- Value = CAR_2017_control_pc
- Color ramp = Blues



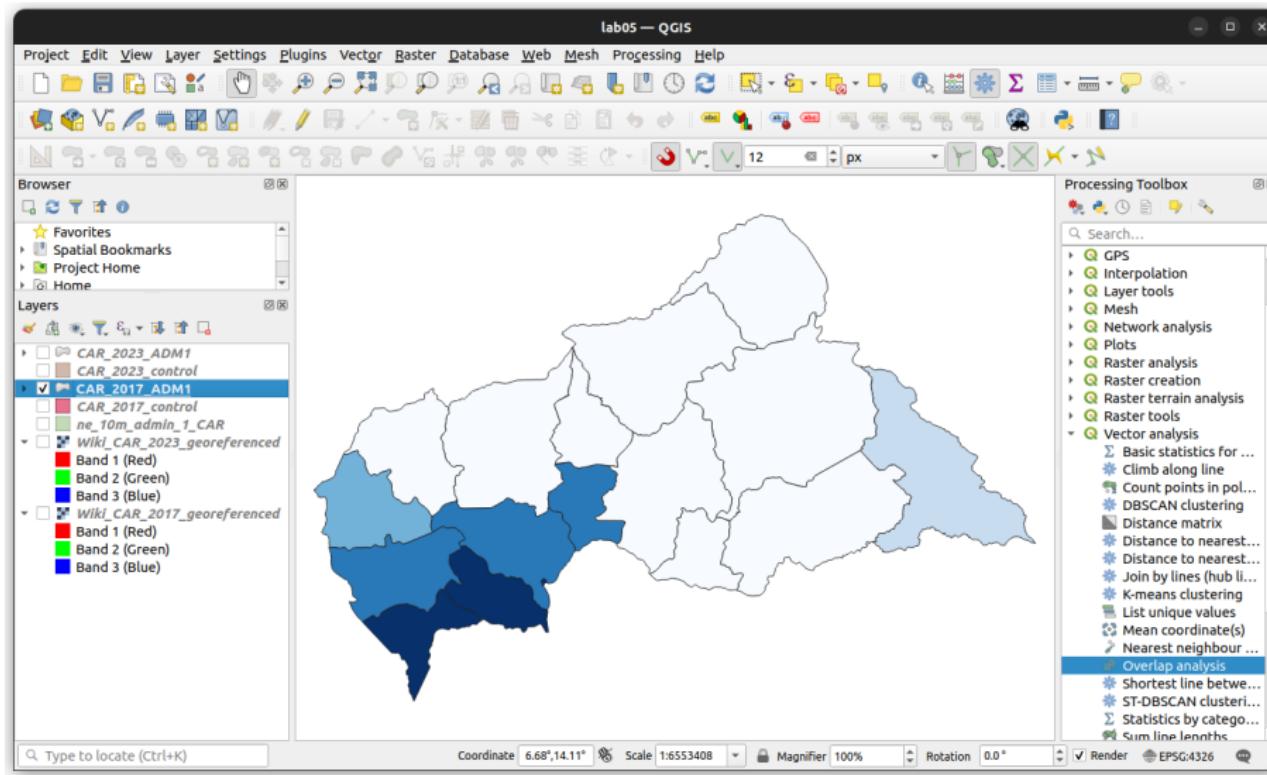
Set

- Mode = Pretty Breaks
- Click Classify

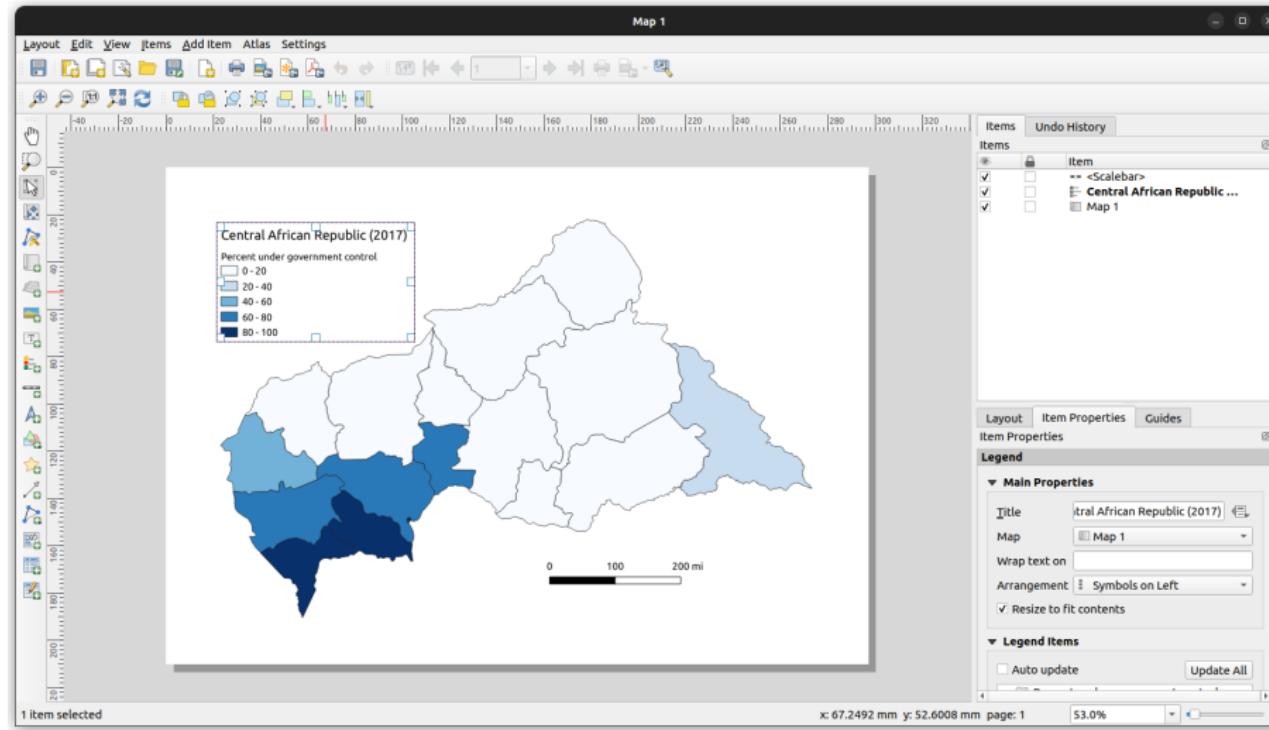
Click OK



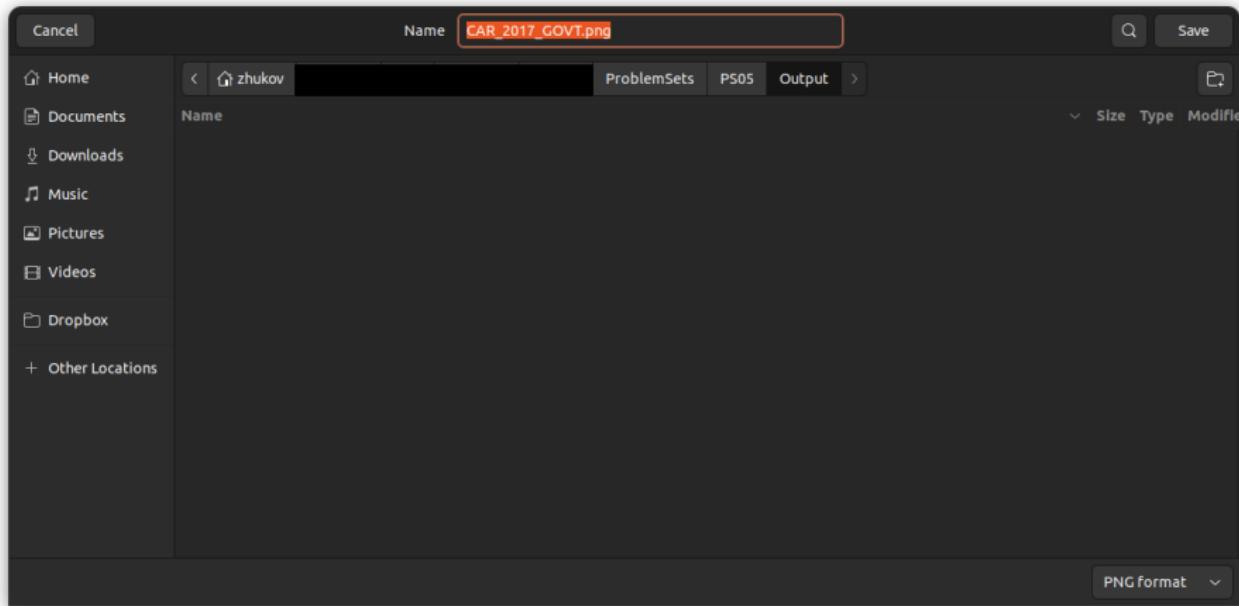
The province polygons should now be colored according to percent of territory controlled by the government



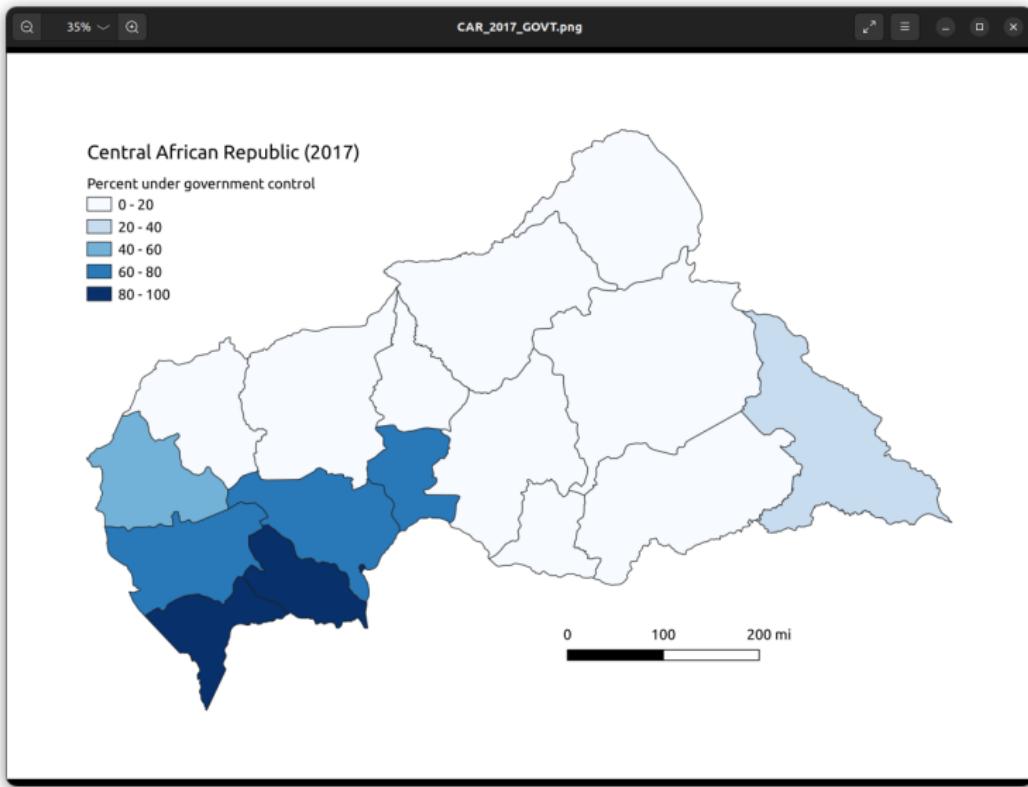
Make a New Print Layout, fixing the legend as always and adding a scale bar



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, 2017-2024
- vectorize polygons in Wiki_CAR_2024_georeferenced
- do overlap analysis
- create new field: difference between 2024 and 2017
- export the map as an image, showing:
 - provinces colored by 2024-2017 difference
 - legend and scale bar
- name the file CAR_2024_CHANGE.png
- upload to Canvas (by Wed)

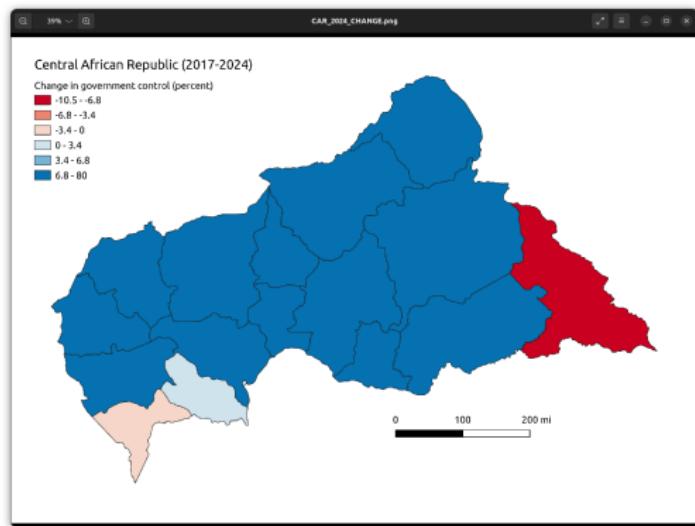
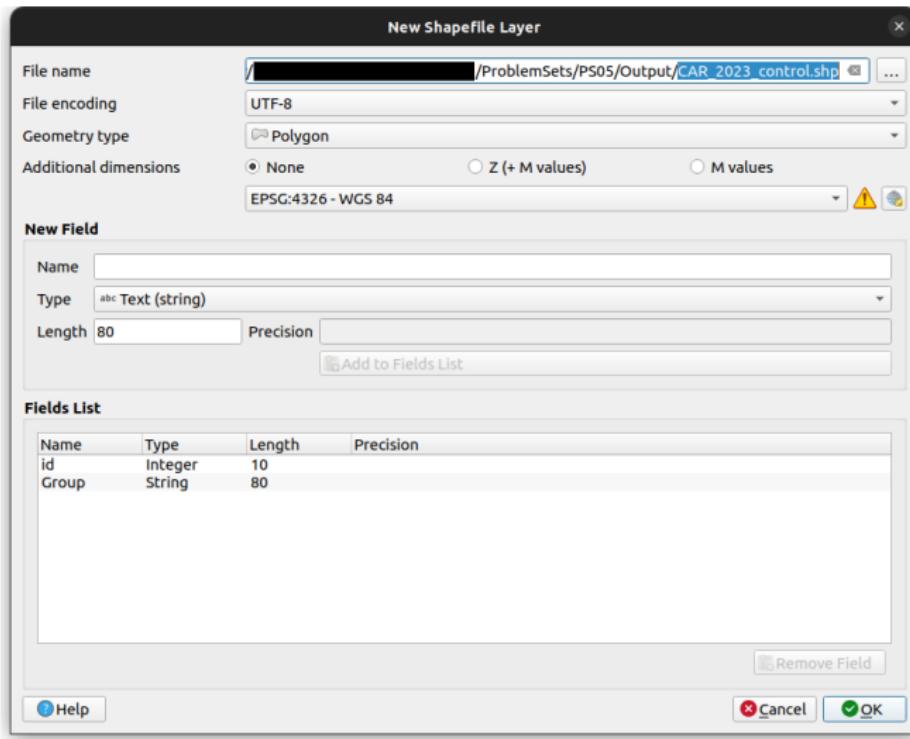
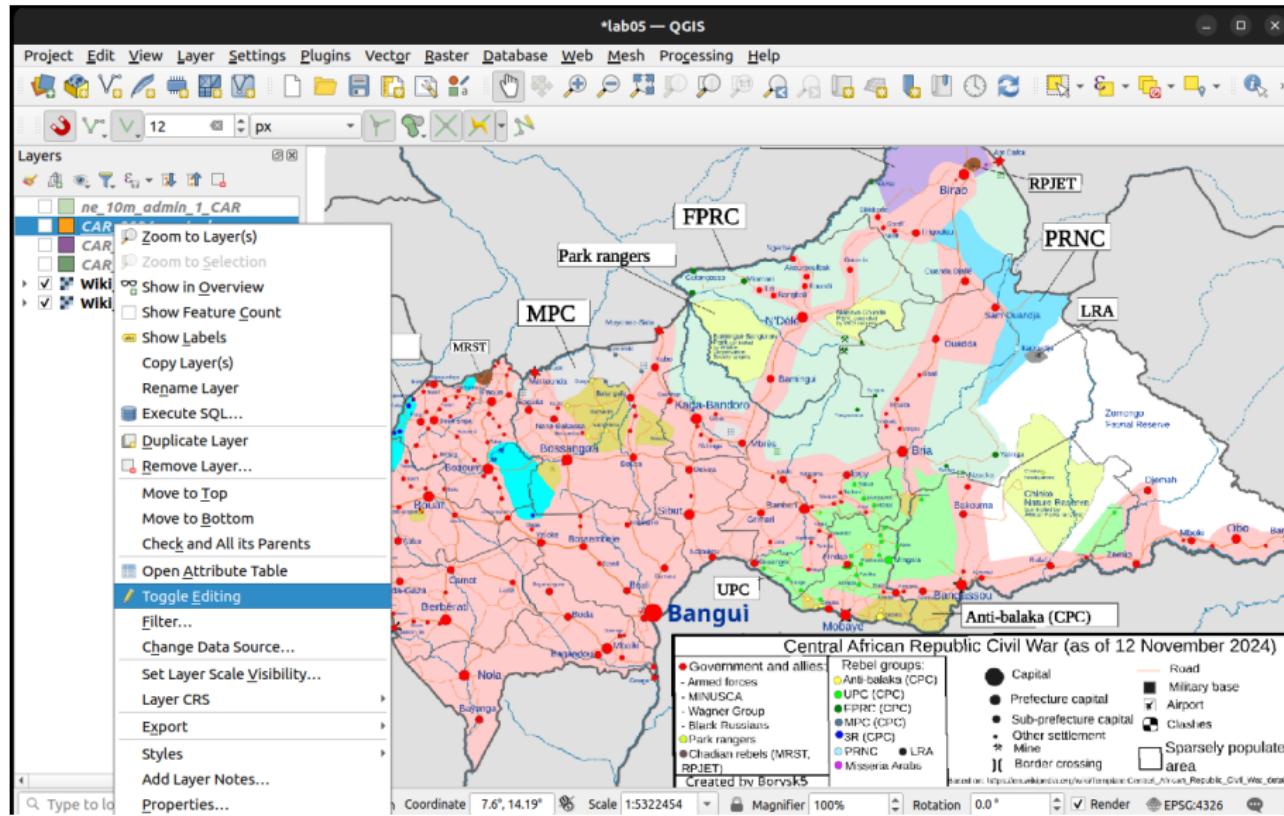


Figure 8: Can you make this map?

Let's preview some of the steps. Create a New Shapefile Layer for 2024:
`CAR_2024_control.shp` (other parameters same as before)



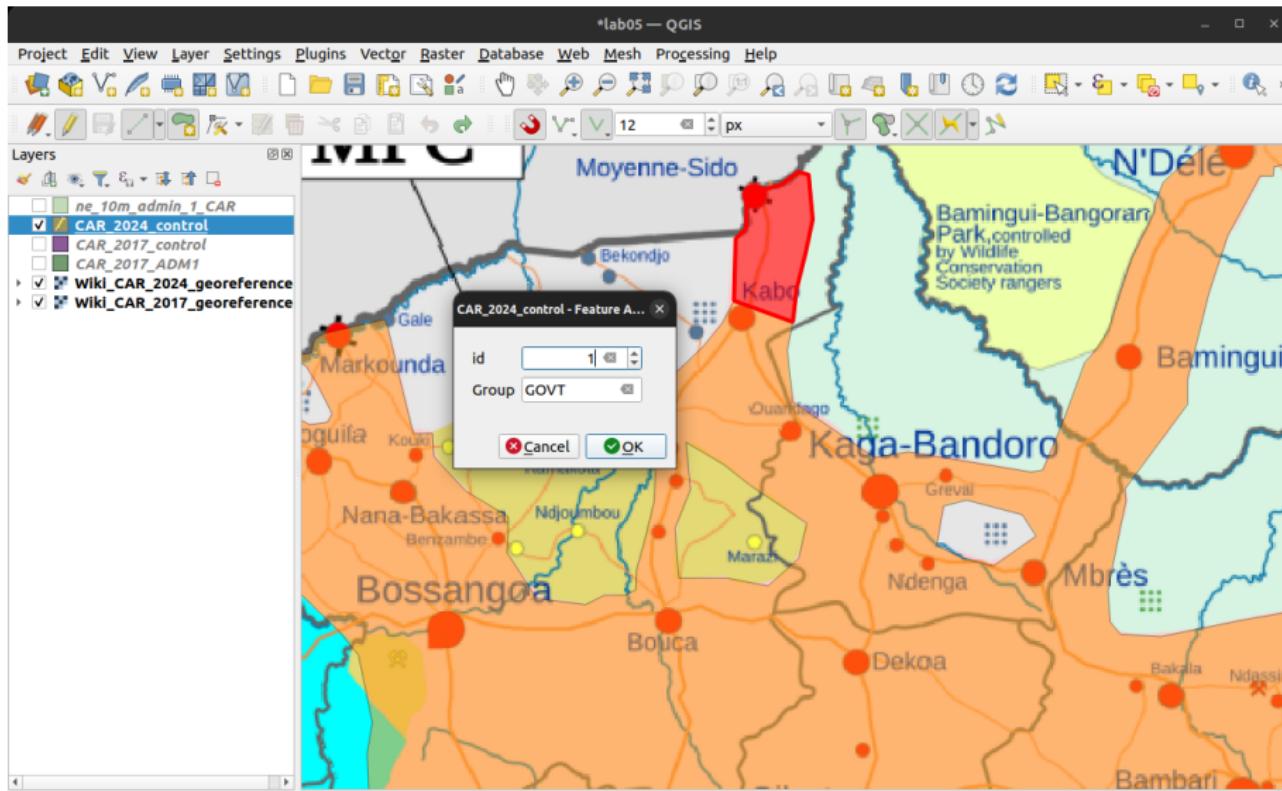
Set the layer to *editing mode* by Right-clicking → Toggle Editing



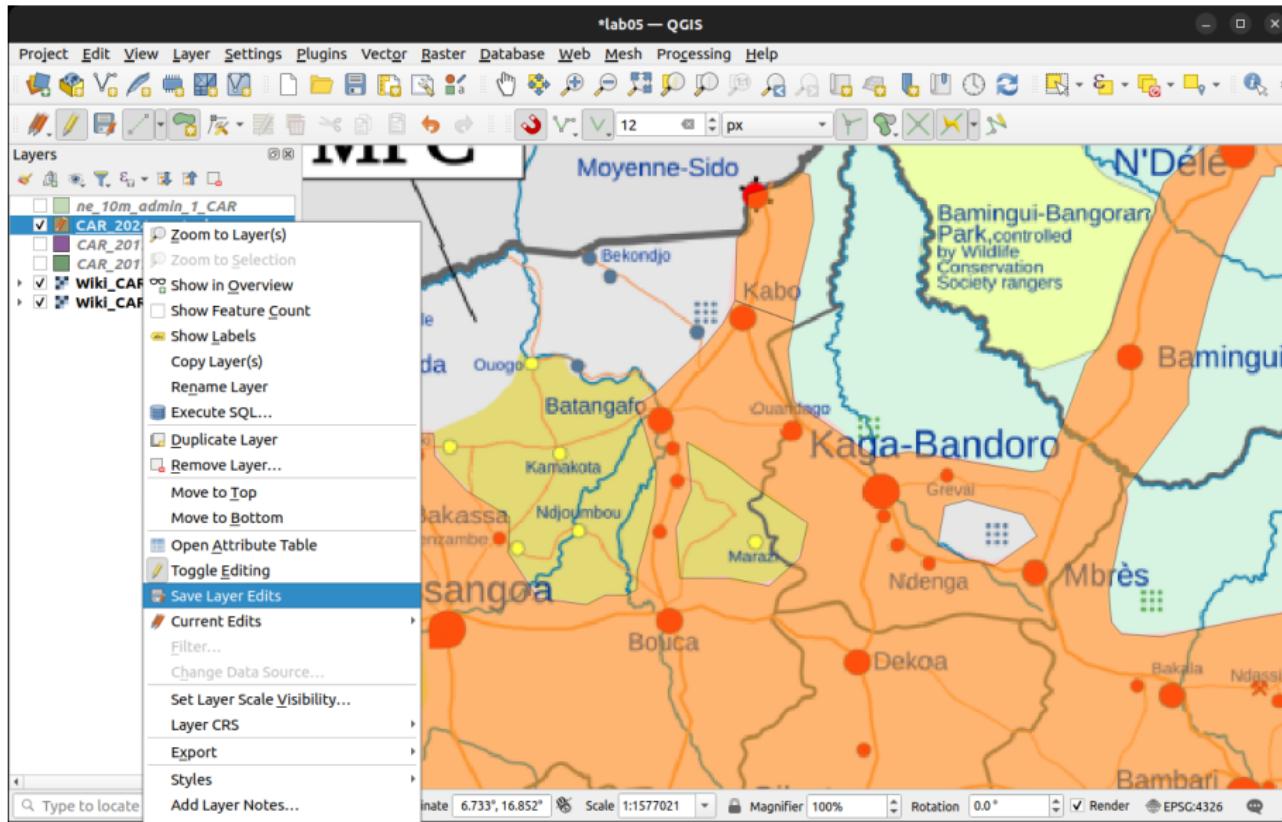
Click on the Add Polygon Feature tool. The snapping parameters should be the same as before



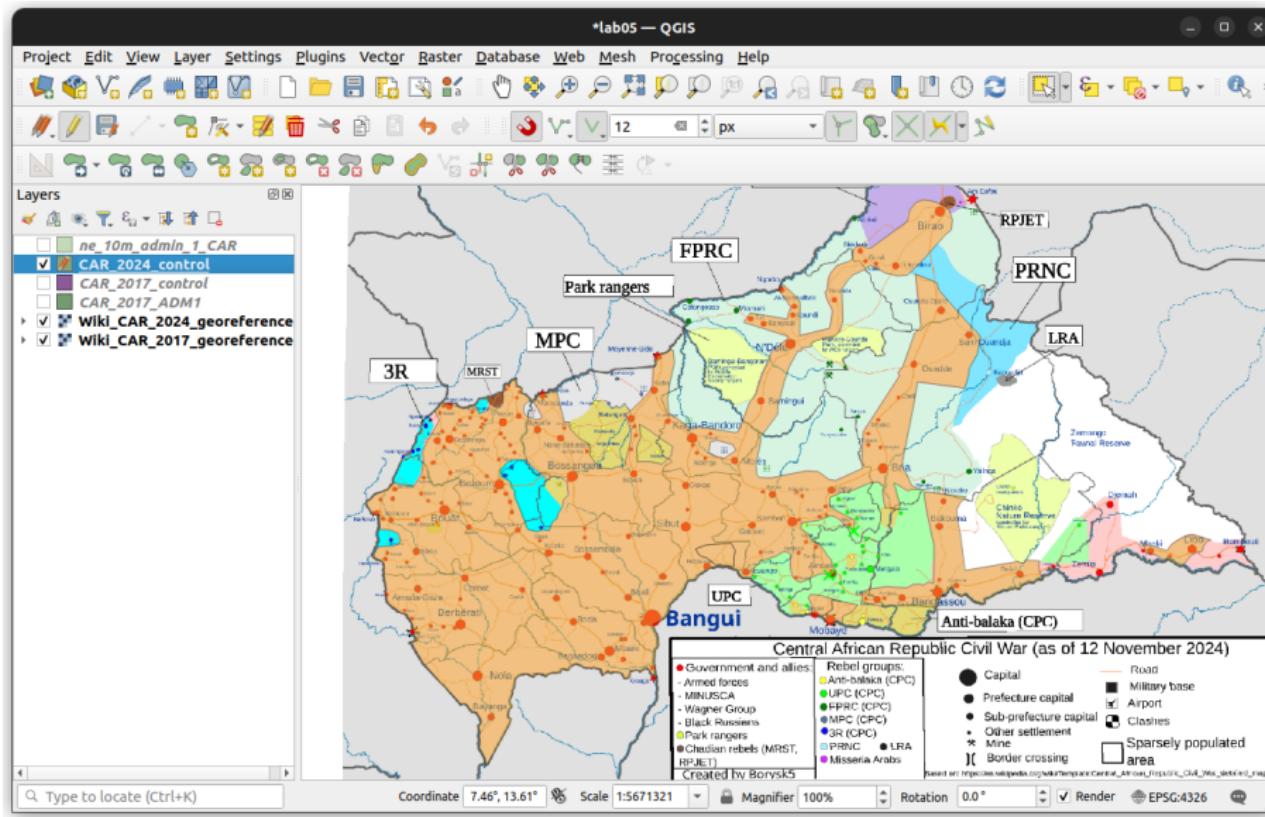
Trace new polygon features and enter field information like before (remember to hide the inactive layers while you do this)



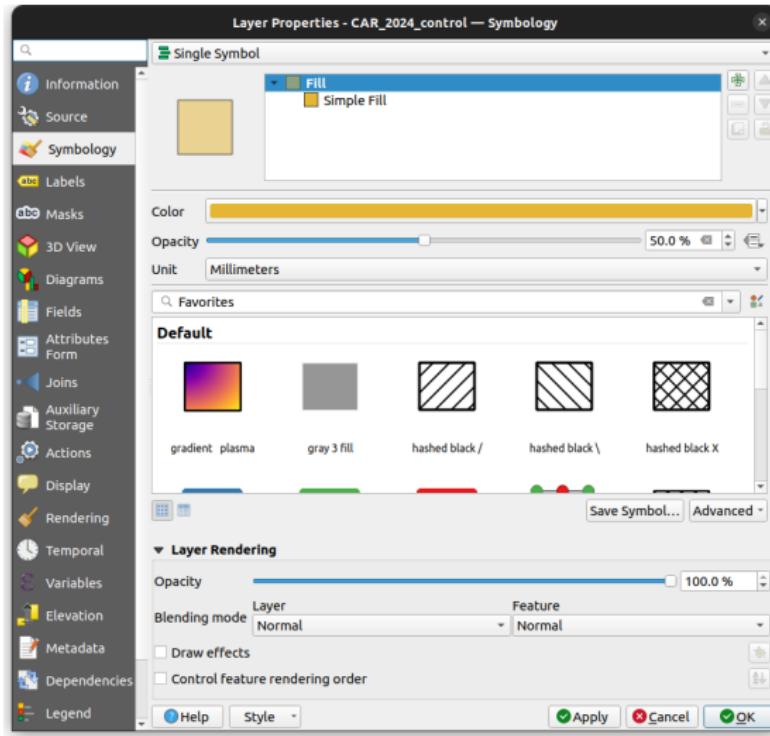
Save your progress as you go.



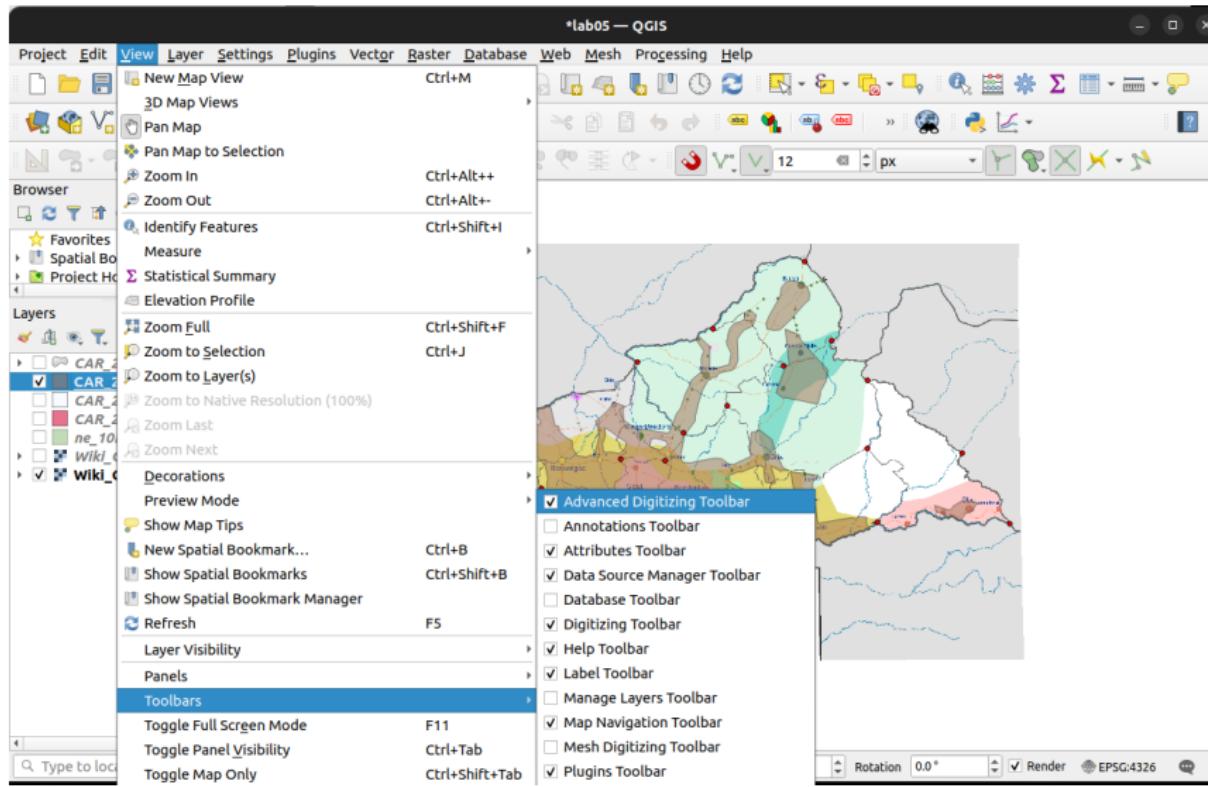
But how do we *create holes in polygons* to account for more complex geometries?



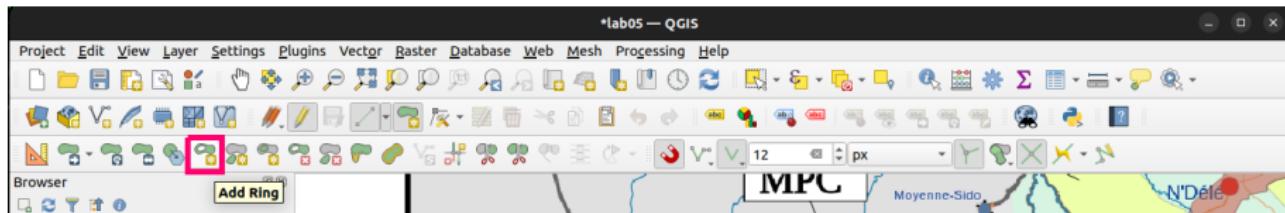
Start by making the CAR_2024_control layer semi-transparent (Opacity = 50%), so we can see the raster underneath



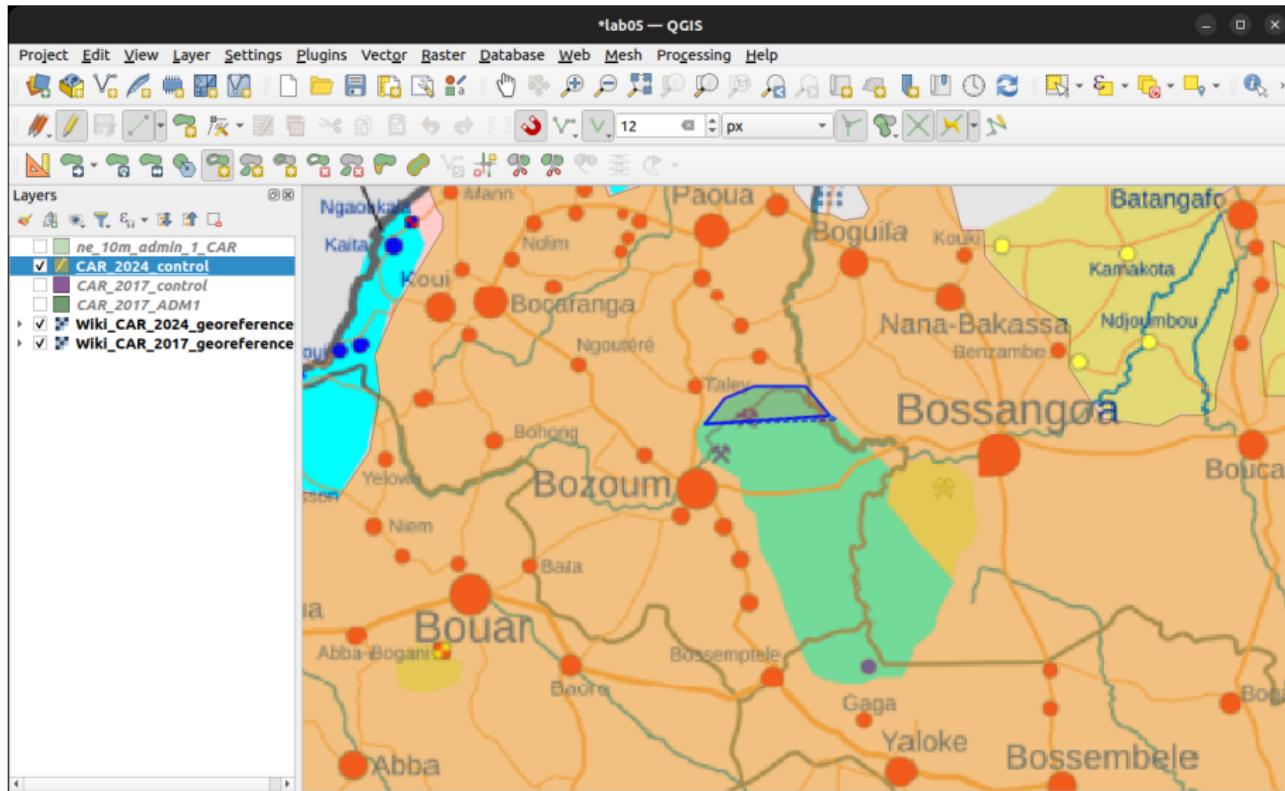
The tool we need is in the Advanced Digitizing Toolbar. To access it, go to View → Toolbars → check box next to Advanced Digitizing Toolbar



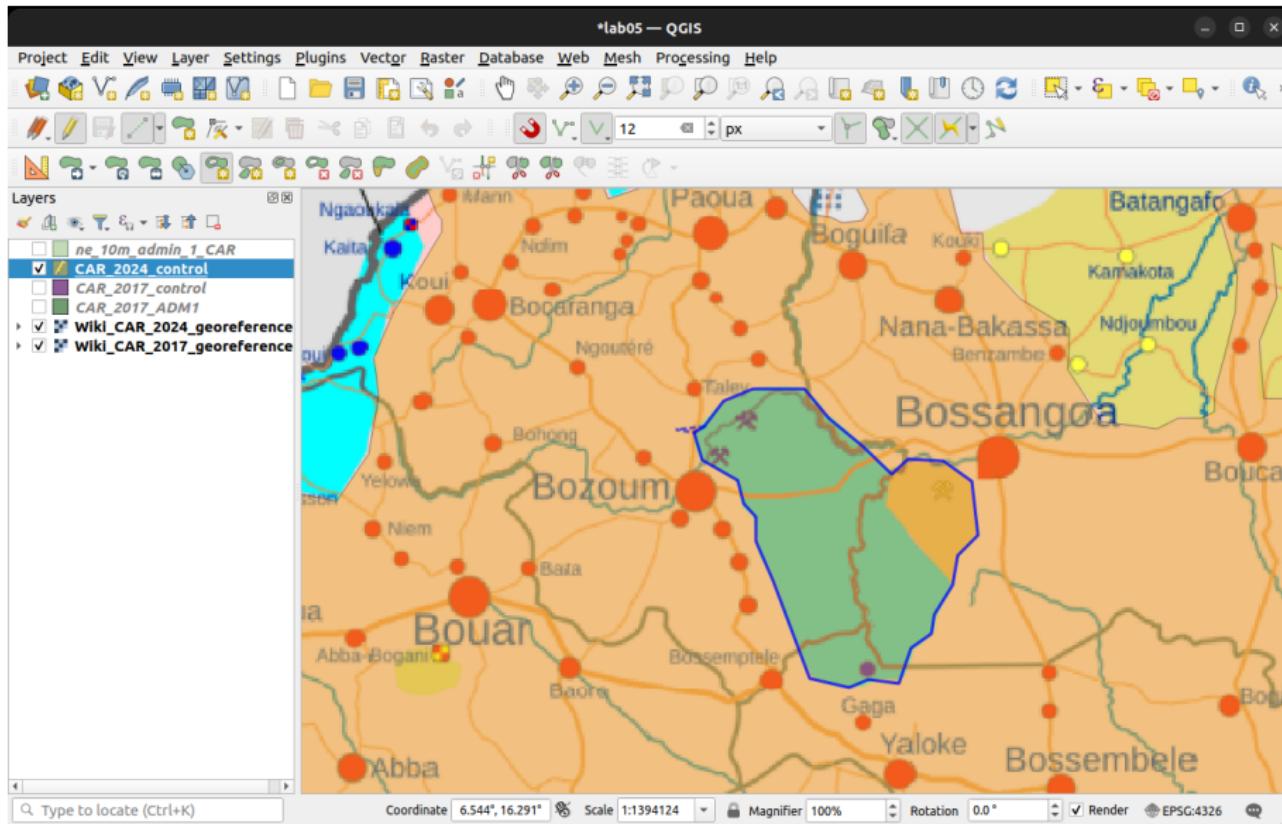
Click on Add Ring tool in the Advanced Digitizing Toolbar
(green blob with a hole in it, yellow star)



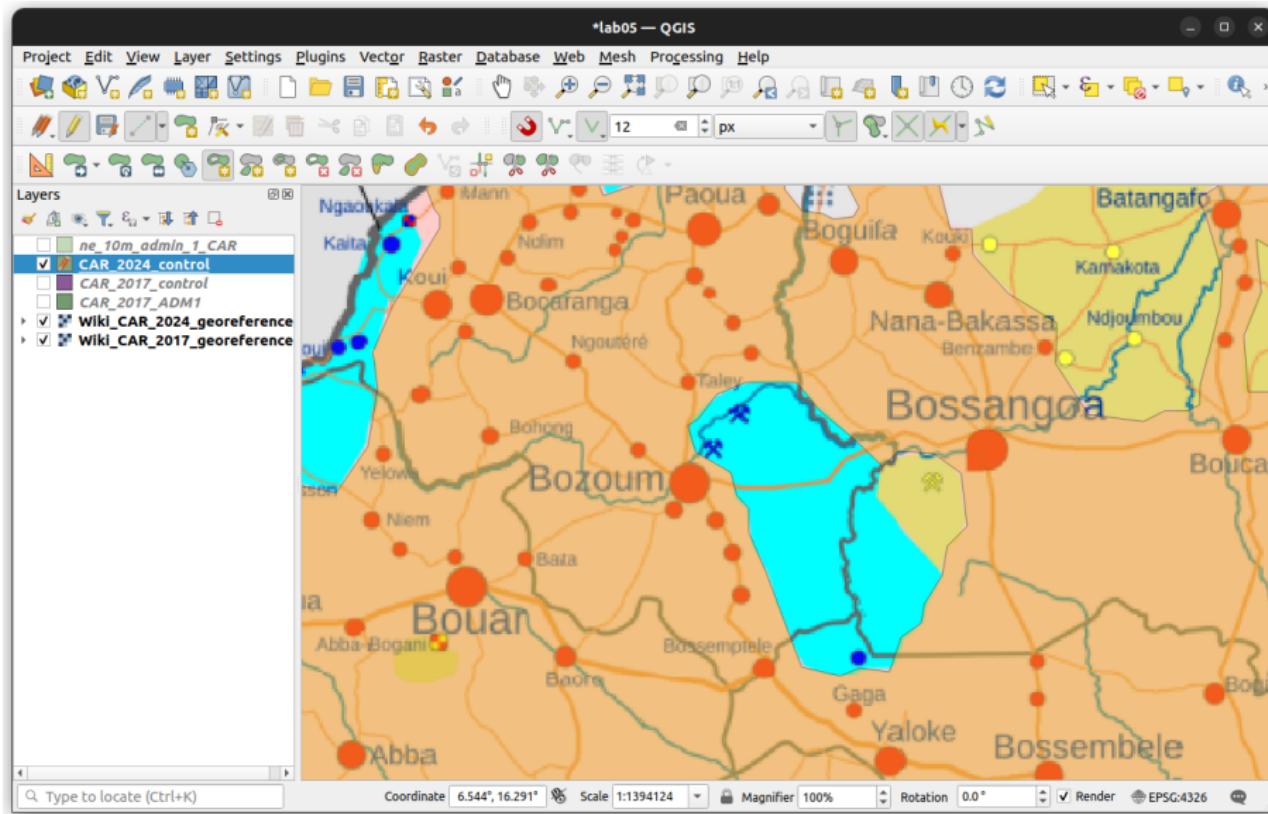
Using the Add Ring tool, trace the contour of the first polygon hole, as if you were tracing another polygon



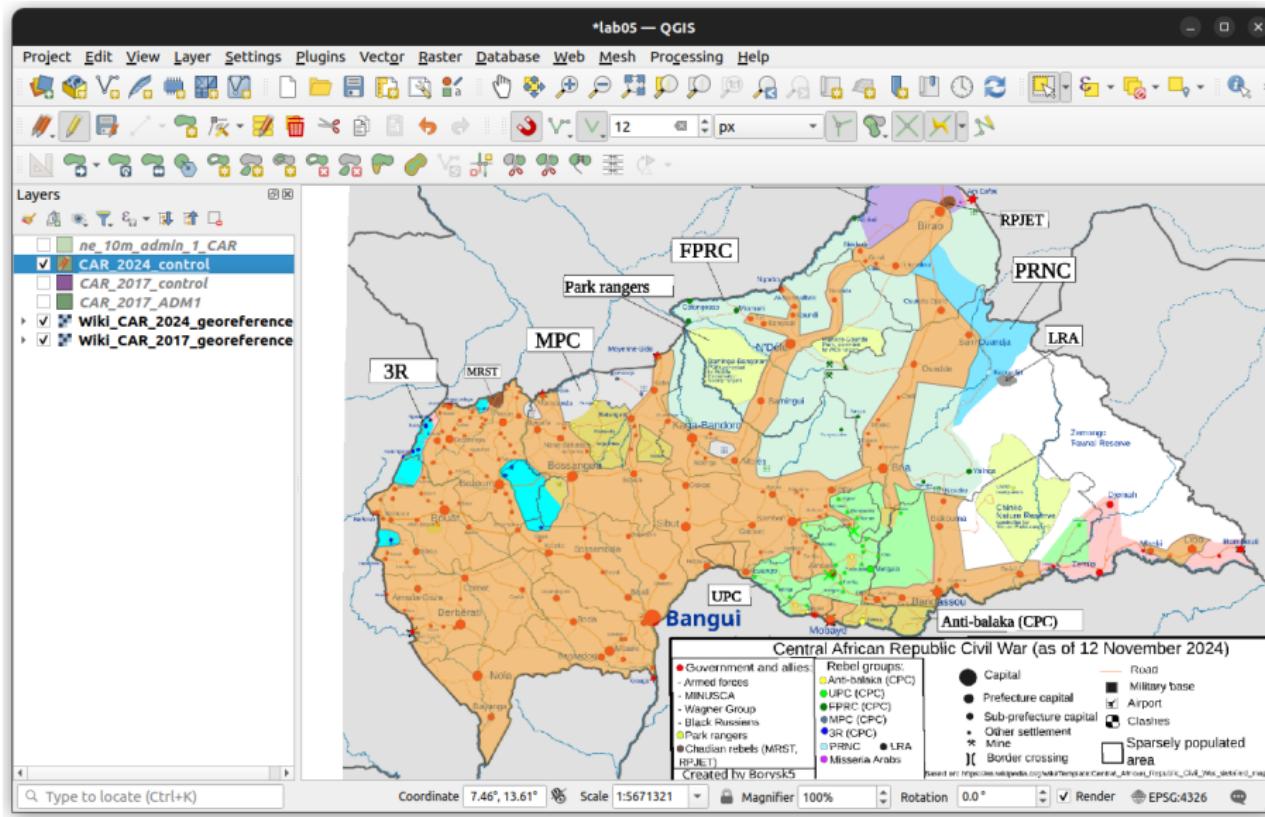
To close the loop, right-click anywhere on the screen



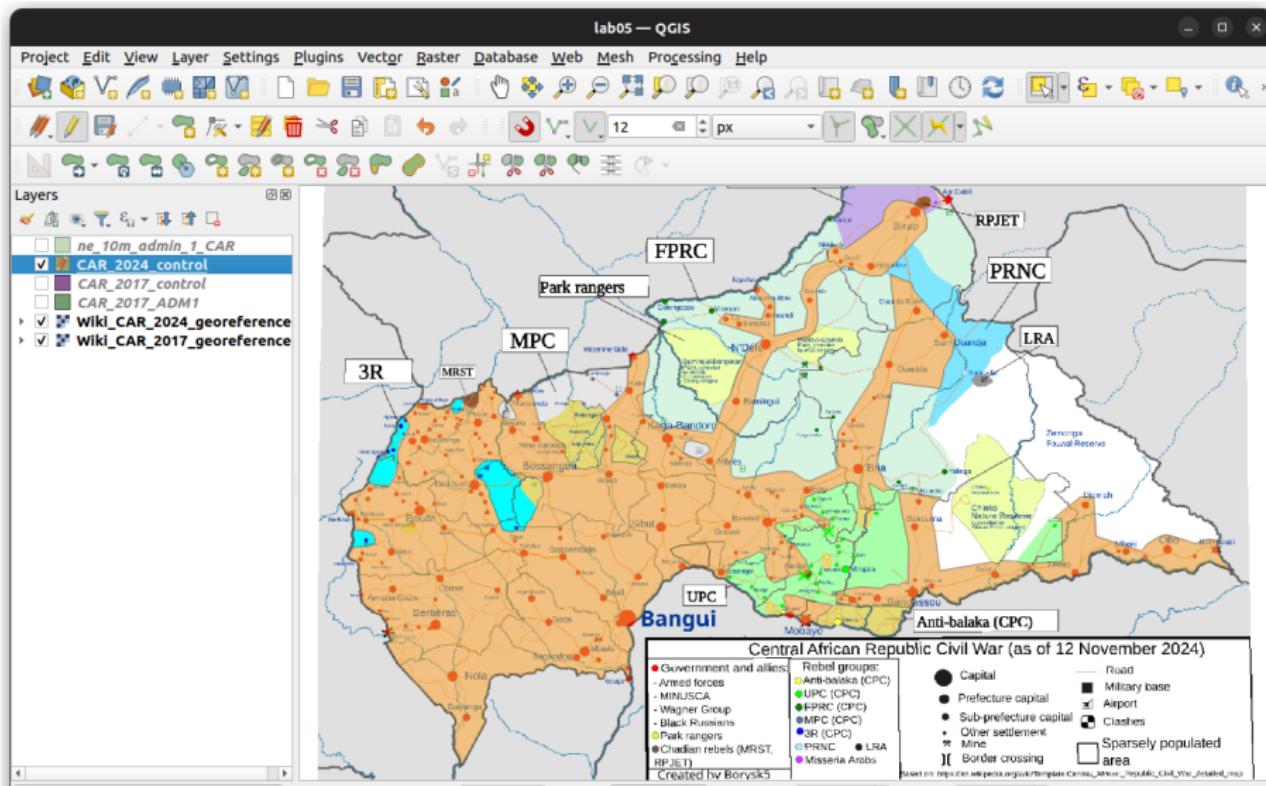
This should add a hole to the polygon you had vectorized



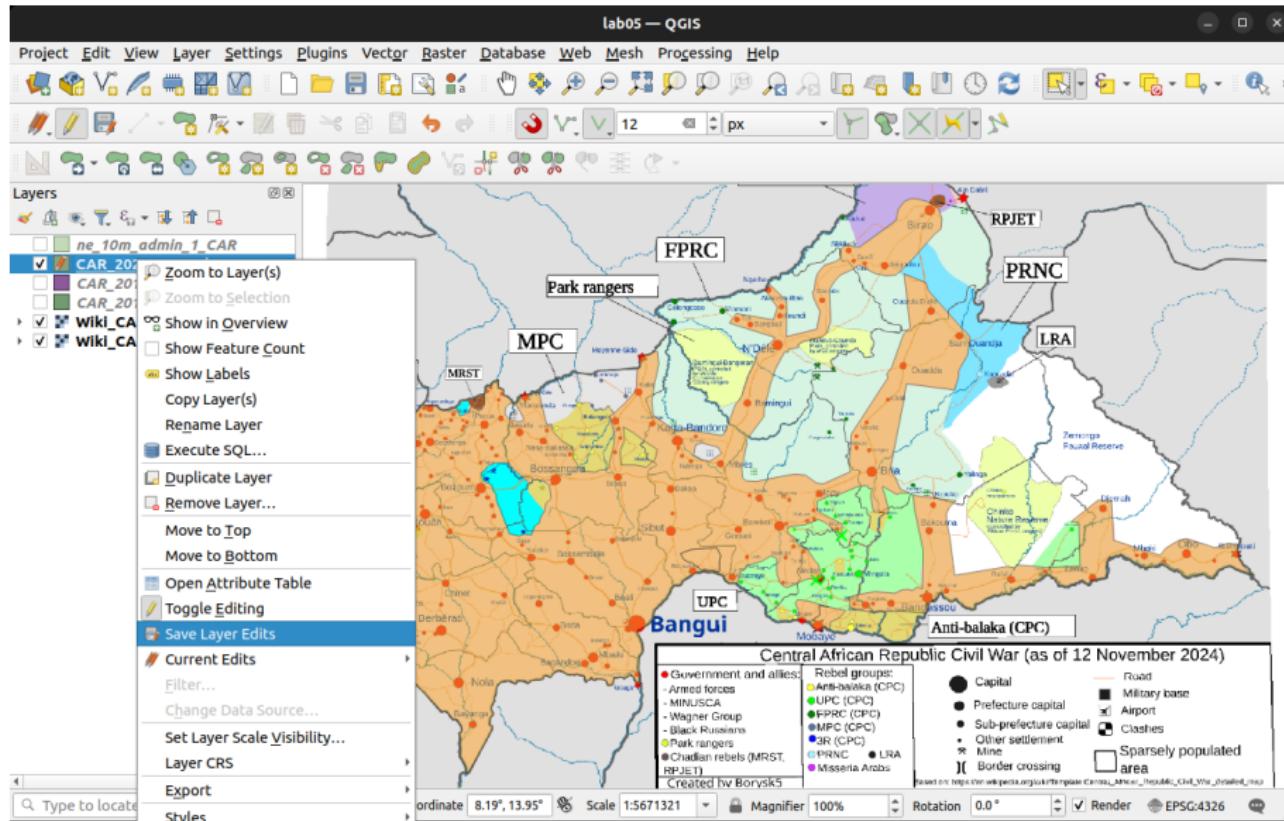
Repeat this process for each hole you need to carve out



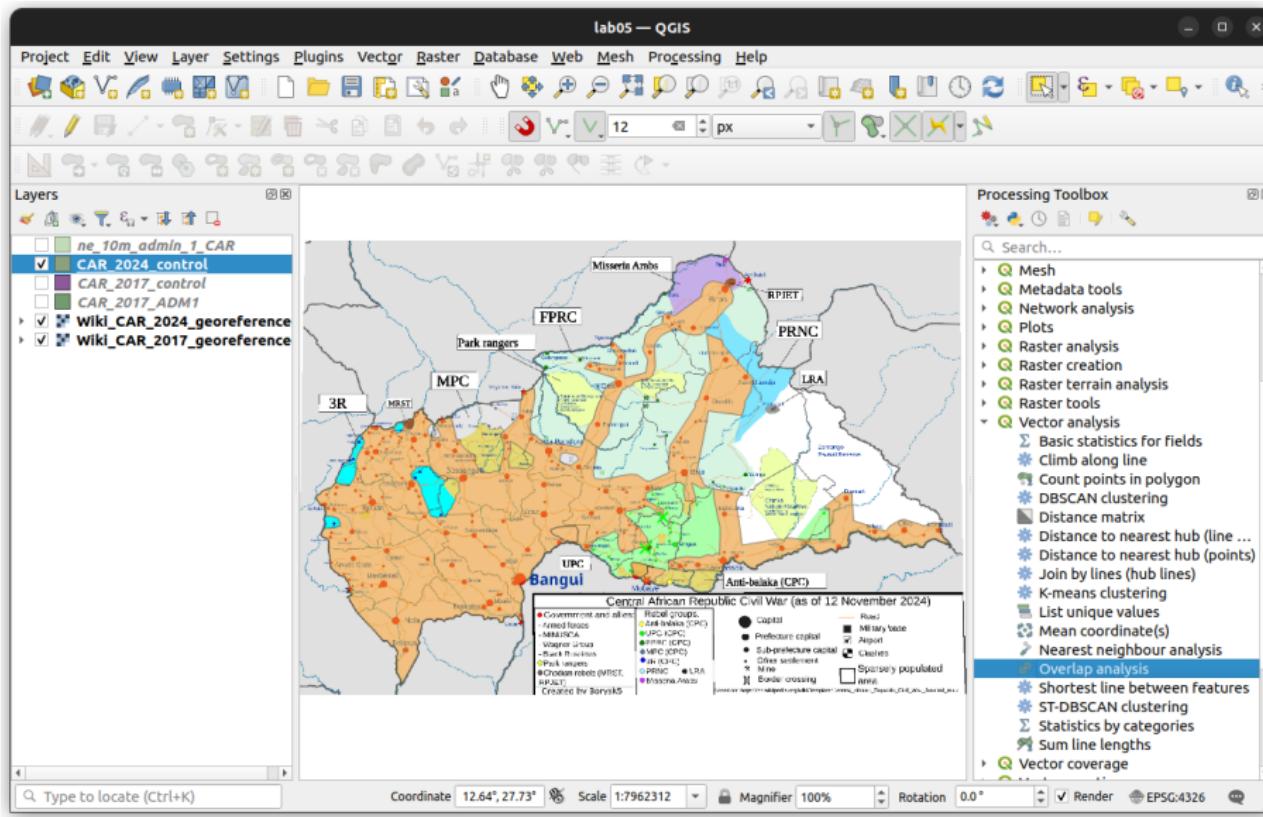
Add the remaining government-controlled polygons (there should be several non-contiguous government polygons here)



Save your progress and leave editing mode

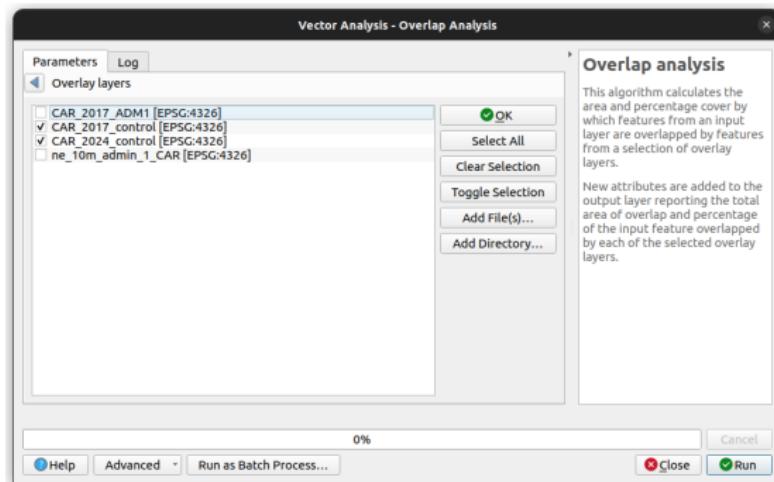


Go back to the Overlap analysis tool



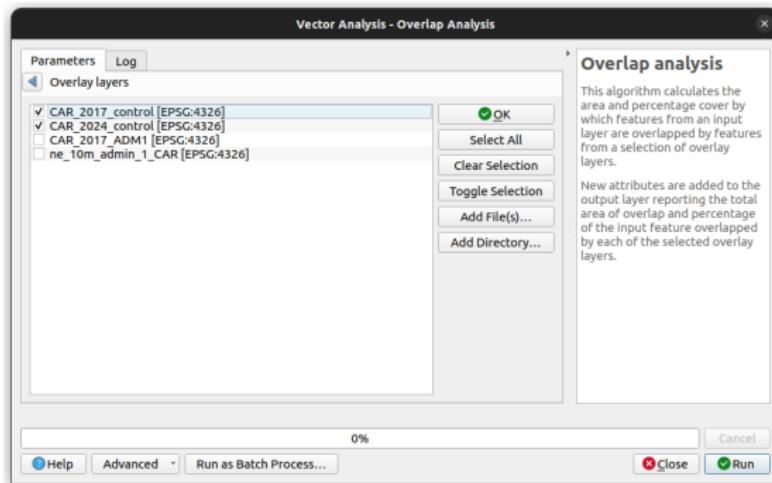
In the Overlap Analysis window, set

- Input layer = ne_10m_admin_1_CAR



Set

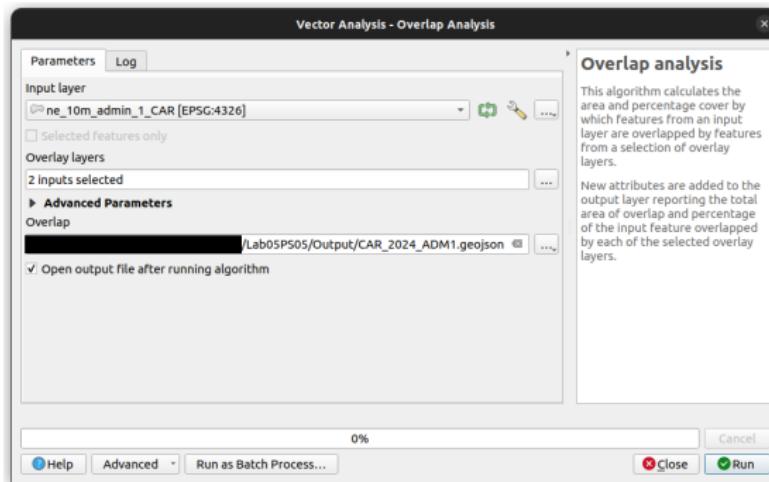
- Overlay layers = CAR_2017_control, CAR_2024_control (select both)



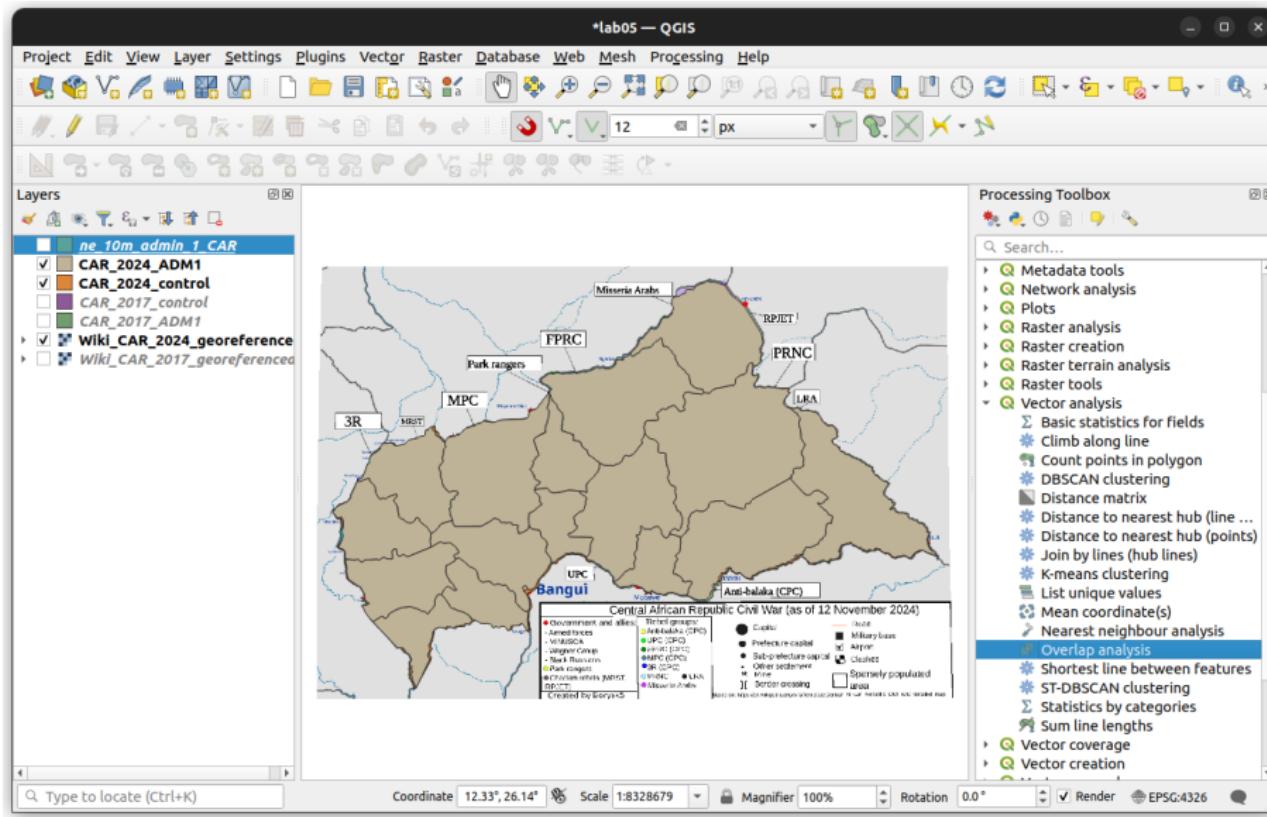
Set

- Overlap (file output) = CAR_2024_ADM1.geojson in Output folder.

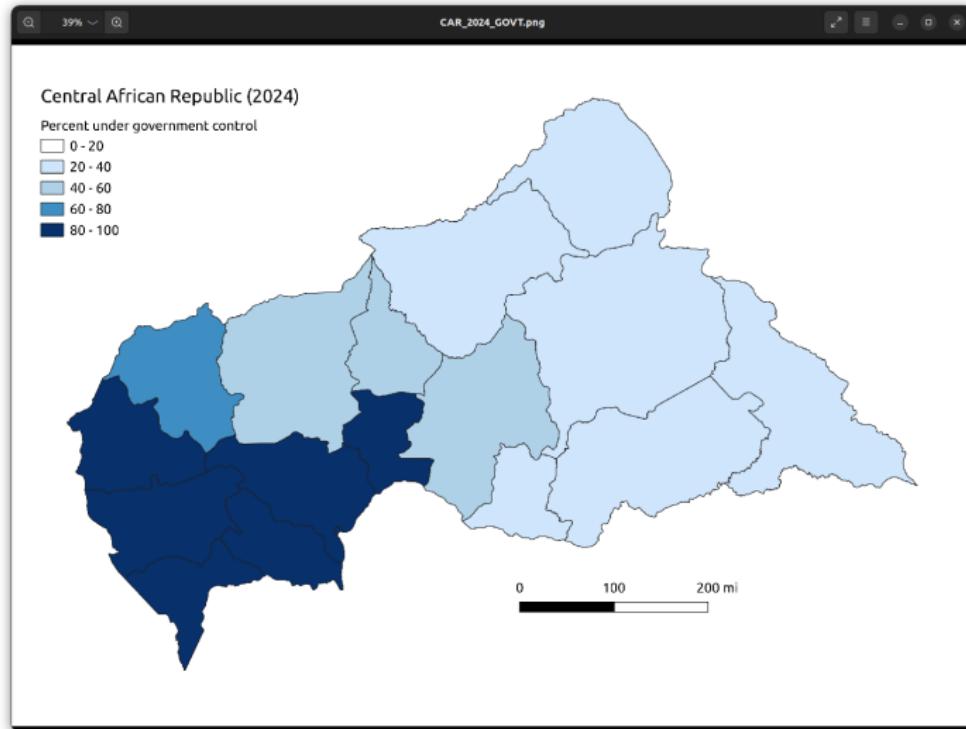
Click Run



The new layer CAR_2024_ADMIN1 should appear in the map and Layer menu



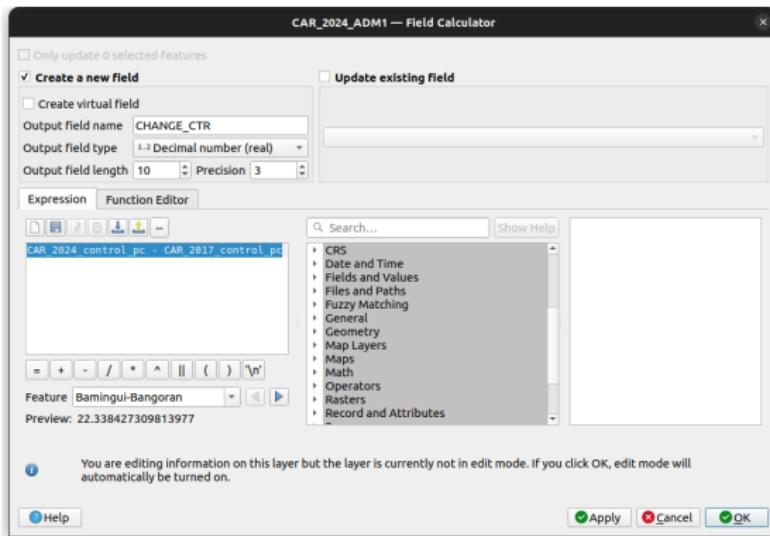
If you want, you can use this map to create the 2024 counterpart to the first image we created (for practice only; this is not required and not part of the assignment)



Let's calculate the difference between 2024 and 2017. Open the Attribute Table for CAR_2024_ADM1, go to Field Calculator

CAR_2024_ADM1 — Features Total: 17, Filtered: 17, Selected: 0												
IS_ID	FCLASS_PL	FCLASS_GR	FCLASS_IT	FCLASS_NL	FCLASS_SE	FCLASS_BD	FCLASS_UA	FCLASS_TLC	2017_control	2017_contro	2024_control	2024_contro
1	NULL	0	0	132173502...	29.080210...							
2	NULL	0	0	217829166...	25.421238...							
3	NULL	191278357...	34.418479...	134408190...	24.185305...							
4	NULL	113578222...	69.263207...	163980598...	100							
5	NULL	574347132...	11.676797...	244132075...	49.633412...							
6	NULL	0	0	386466972...	23.052436...							
7	NULL	66158290...	0.1104186...	175146580...	29.232075...							
8	NULL	251140606...	79.193231...	311226901...	98.140497...							
9	NULL	93151480...	100	93151480...	100							
10	NULL	184193462...	98.315228...	184505389...	98.481722...							
11	NULL	0	0	129778001...	22.338427...							
12	NULL	612896074	1.1473990	306208782	57.325168...							
Show All Features												

Create new field called CHANGE_CTR of type Decimal number (real). For the Expression, write CAR_2024_control_pc - CAR_2017_control_pc. Click OK



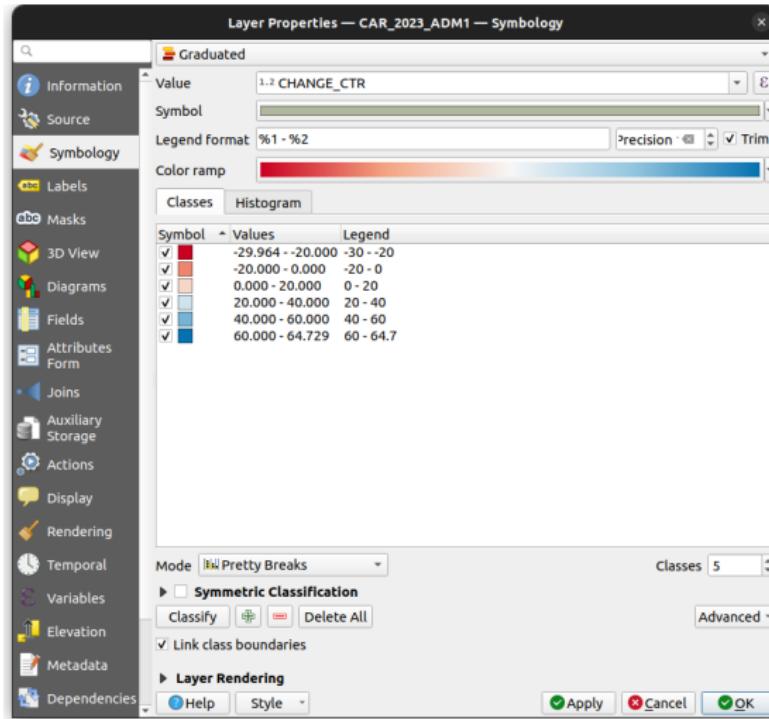
Map this new variable. In Properties, set

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

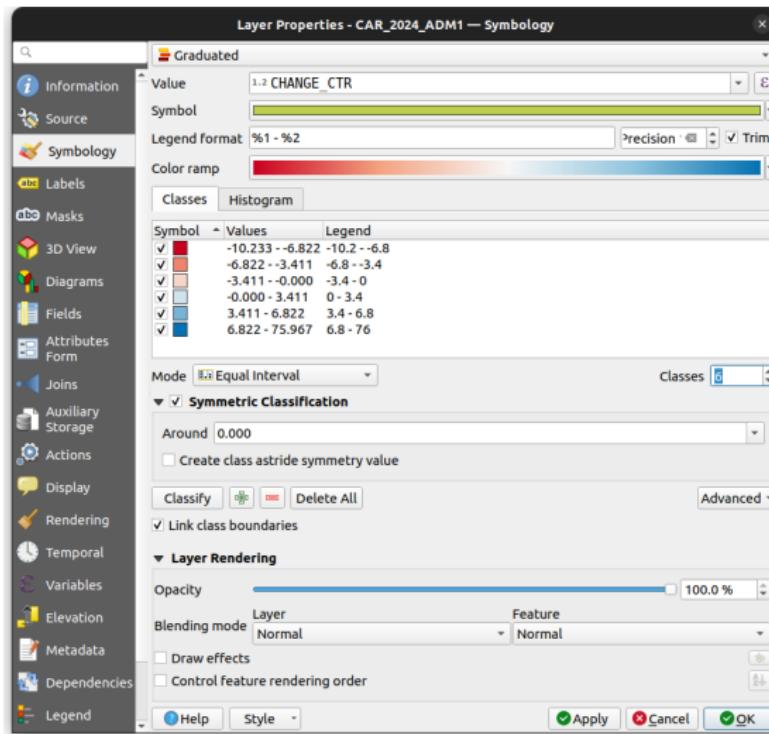


Try setting Mode = Pretty Breaks. Click Classify.

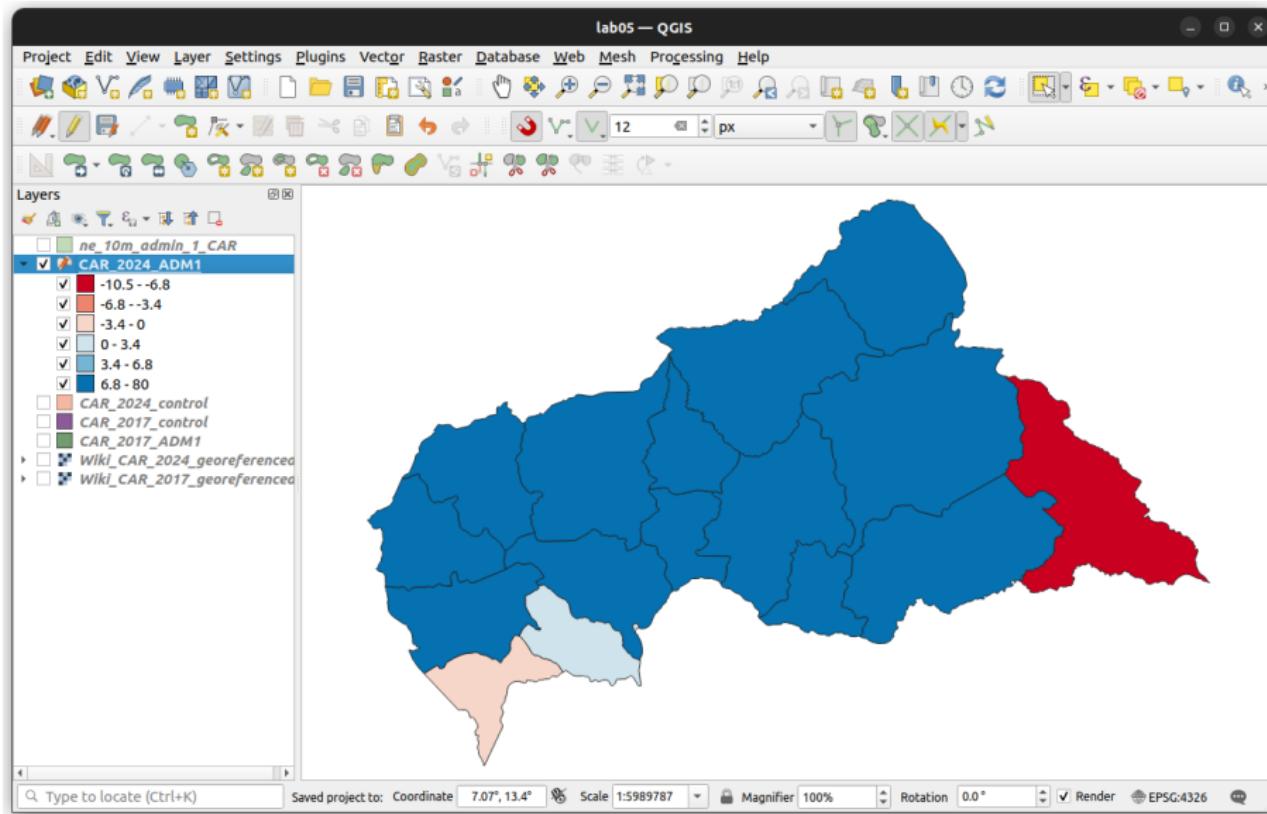
Check to make sure the breaks are *centered on 0* (as they are here). If not...



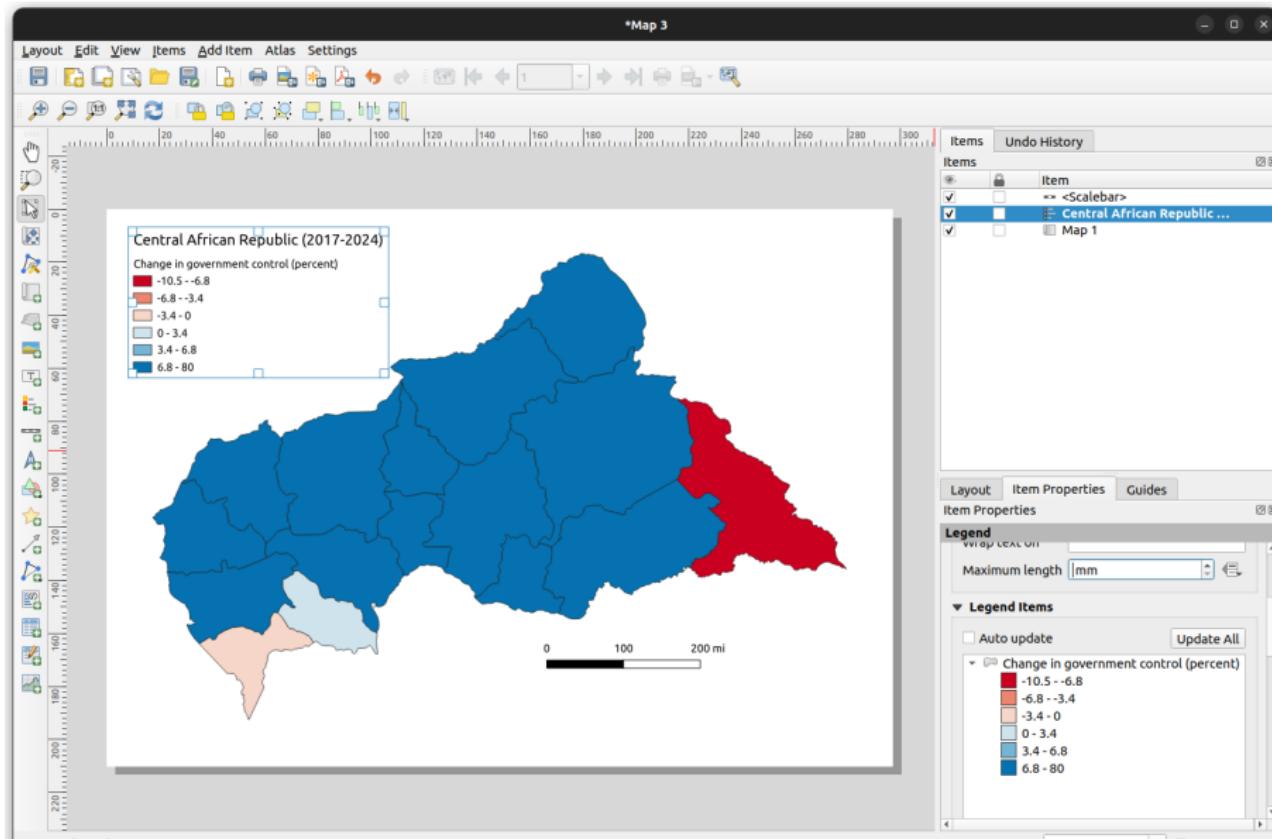
If Pretty Breaks are not centered on 0, switch to Equal Interval with Symmetric Classification set to Around = 0. Click Classify



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!

