

SEST-6577

# **Geographic Information Systems for Security Studies**

## Lab 01 (+ Problem Set 1)

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## Goal: Make our first map!

Steps for lab:

1. Import a shapefile into QGIS/R/py  
(2020 election results in MI)
2. Color the electoral precincts  
**blue** and **red** by vote share
3. Save the map as an image
4. Create and map a new variable:  
`vote margin`

Problem set:

- Repeat these steps for election data from Massachusetts  
(in QGIS, R or Python)

Michigan 2020 Presidential Election Results

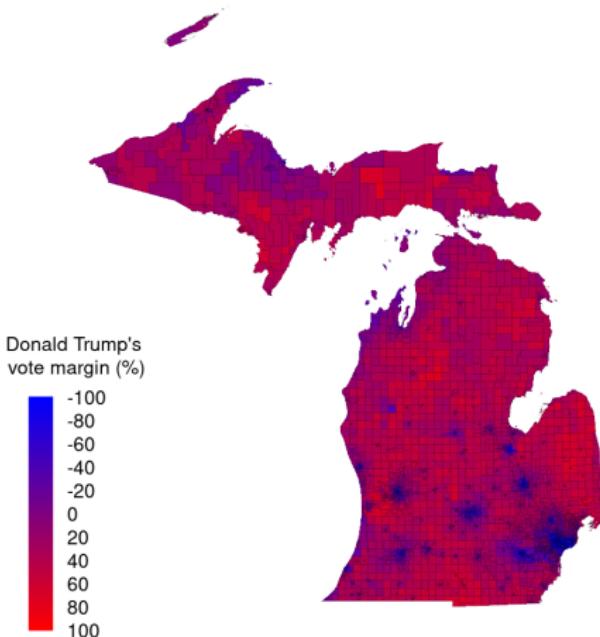


Figure 1: We'll make this

## Data

For this exercise we will be using a precinct-level dataset on 2020 presidential election results for the state of Michigan, `mi_2020`.

Let's get started:

- download `Lab01PS01.zip` from Canvas (`Files → Labs → Lab01PS01.zip`)
- extract zip file to a folder on your hard drive
- the file we need is this: `Lab01PS01/Data/mi_2020.geojson`

Dataset citation info:

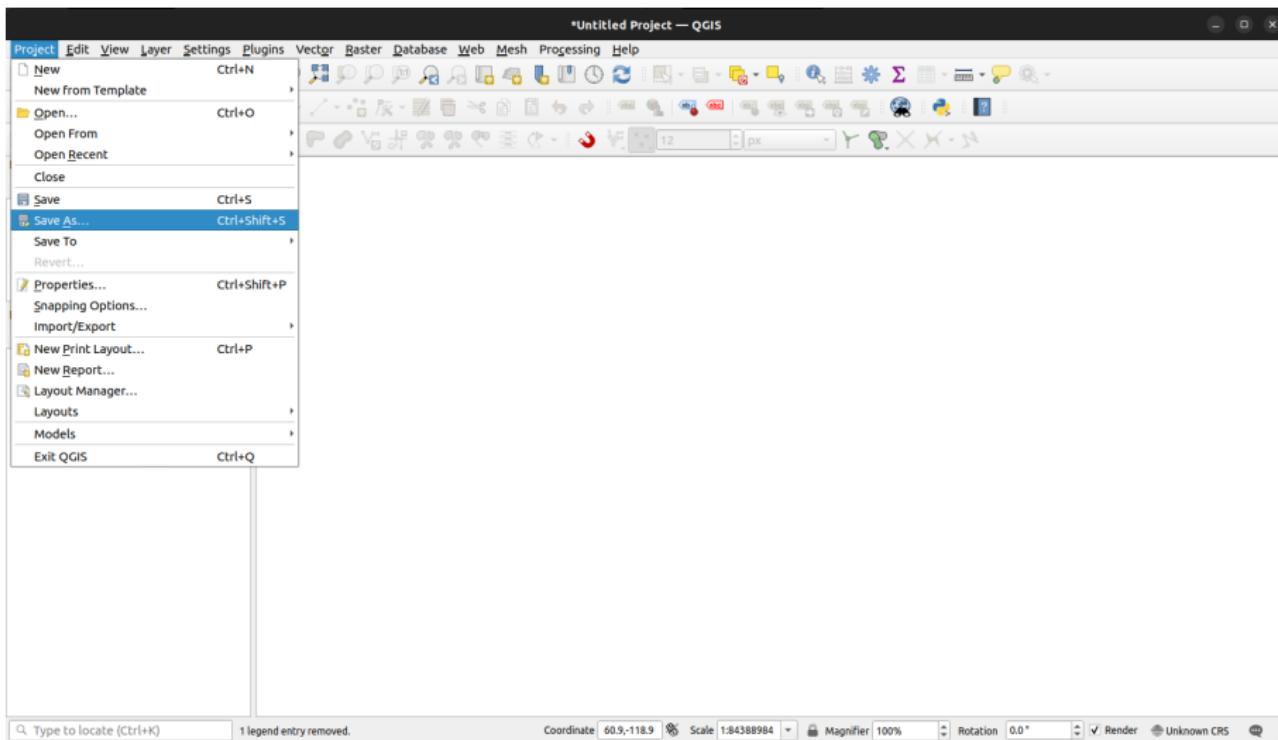
Voting and Election Science Team, 2020, "2020 Precinct-Level Election Results", Harvard Dataverse, V41. [doi.org/10.7910/DVN/K7760H](https://doi.org/10.7910/DVN/K7760H)

# QGIS

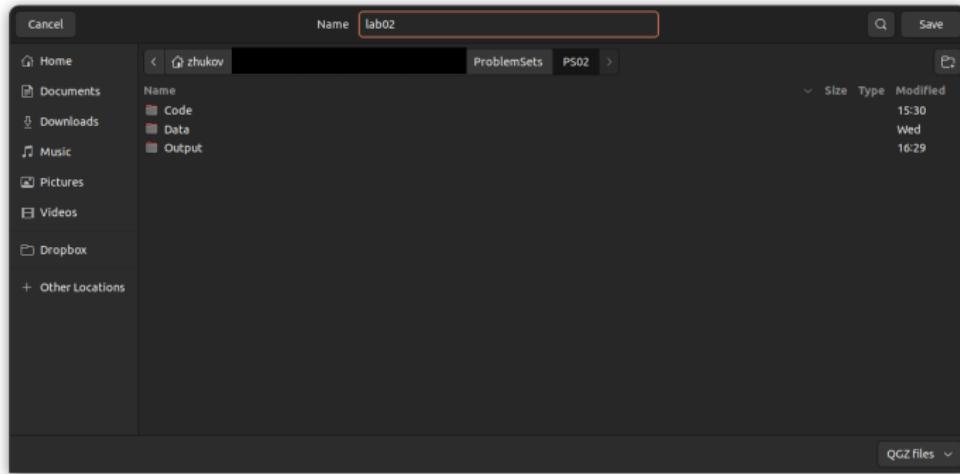
Let's open QGIS!



Figure 2: Get ready to rock!



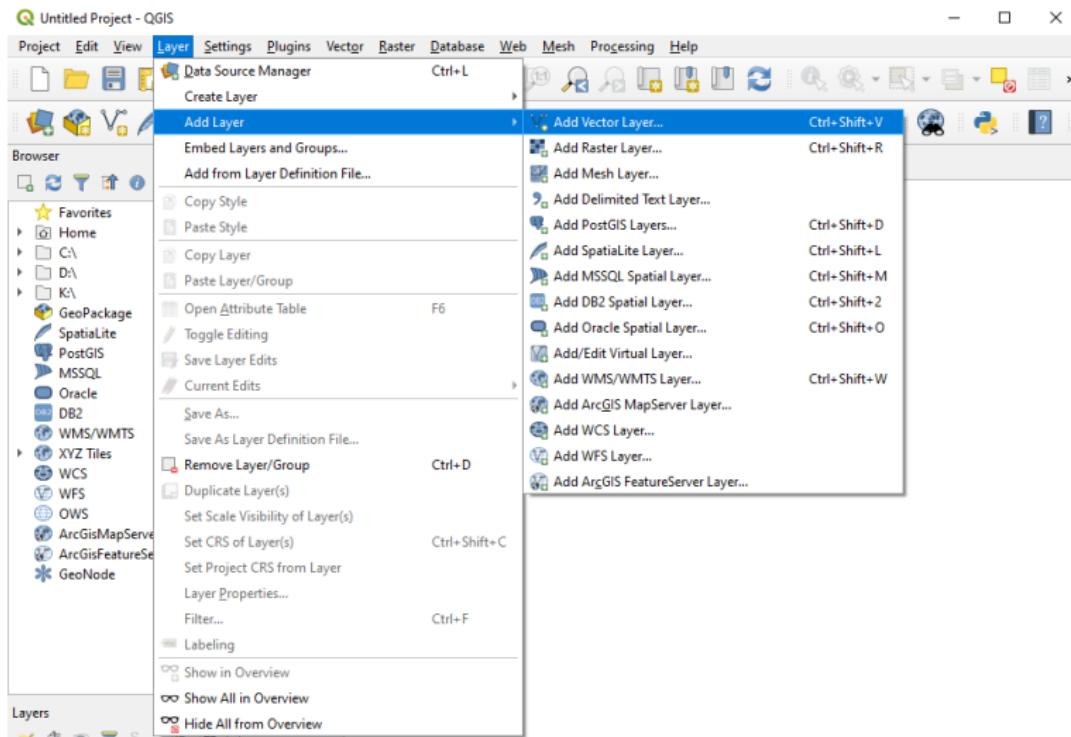
Pro tip: **Save your progress!**  
Go to Project → Save As...



QGIS can save the state of your workspace into a project file

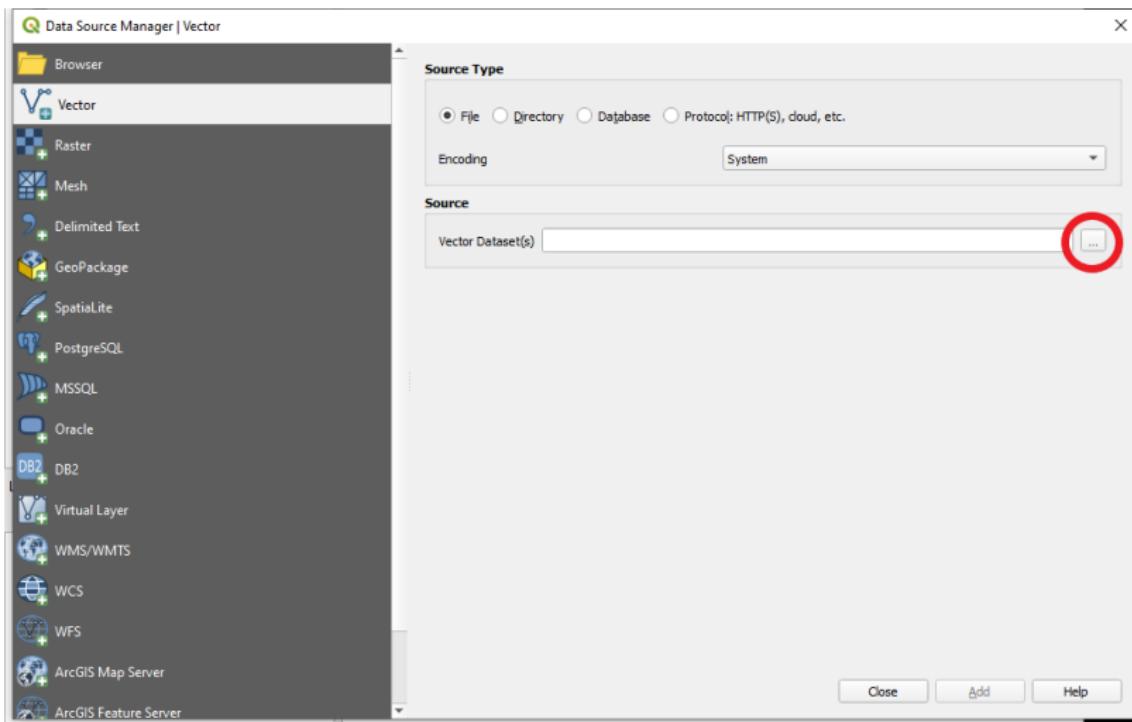
- the extension for QGIS projects is .qgz, a compressed file format
- the .qgz file contains information on your project's layers, symbolization and styles, projections and print layouts
- it does *not* contain your data files, or any temporary files you created
- this can be very helpful if QGIS crashes, so you can pick up where you left off

## Introduction and Demo

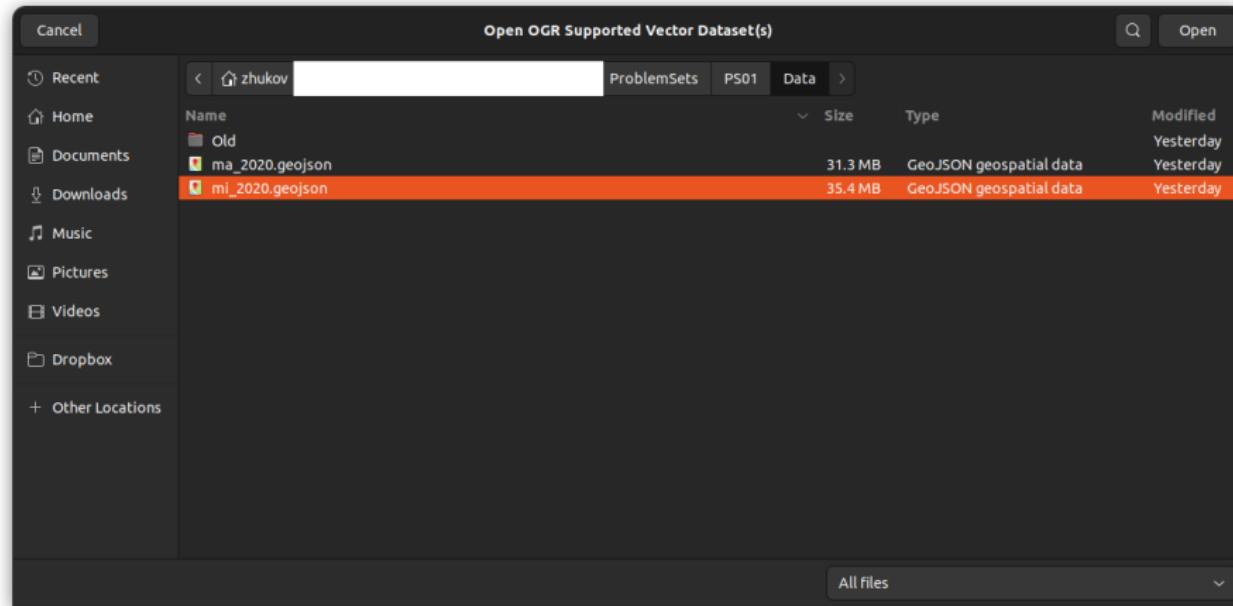


## 1. Load data:

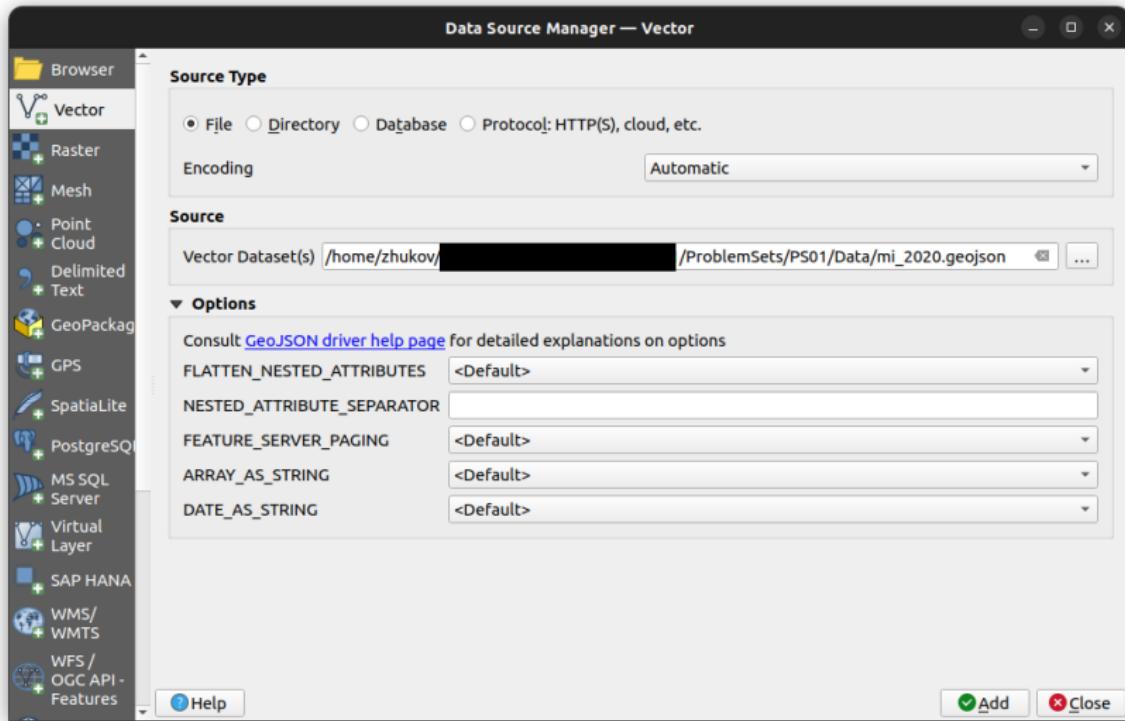
Layer → Add Layer → Add Vector Layer...



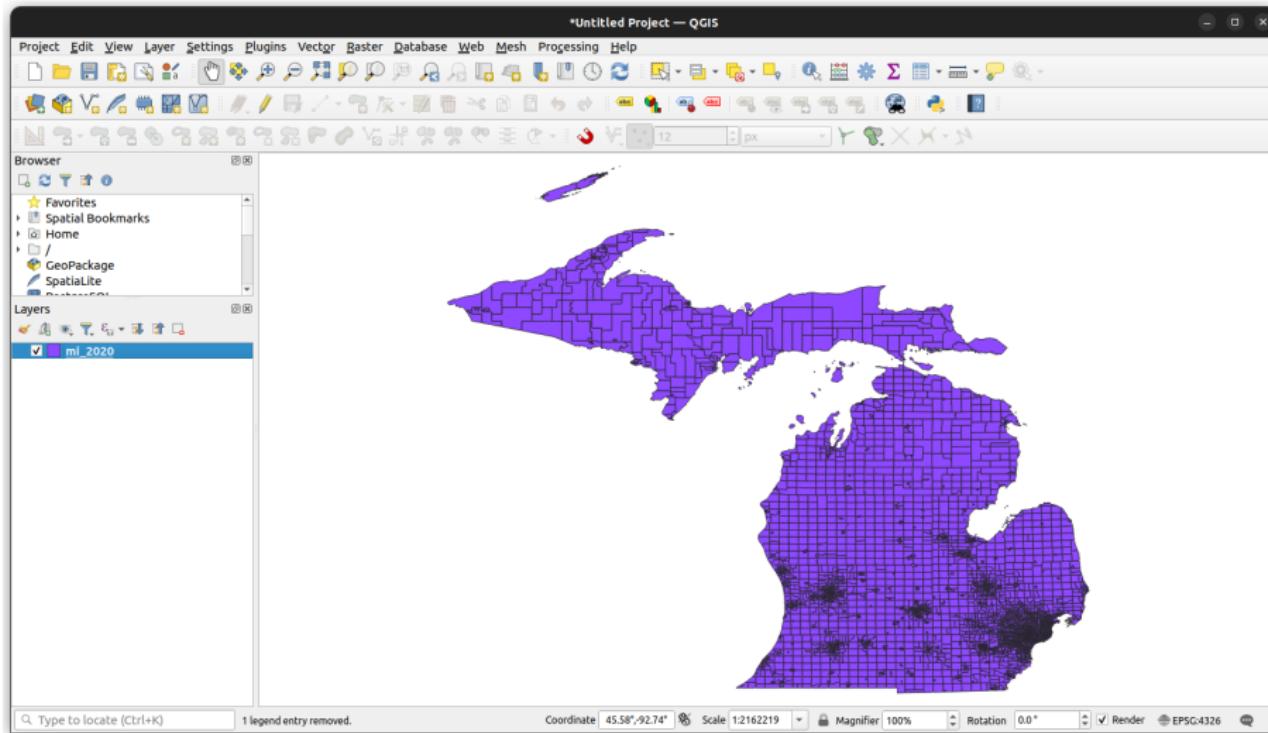
Click on Source → [...]



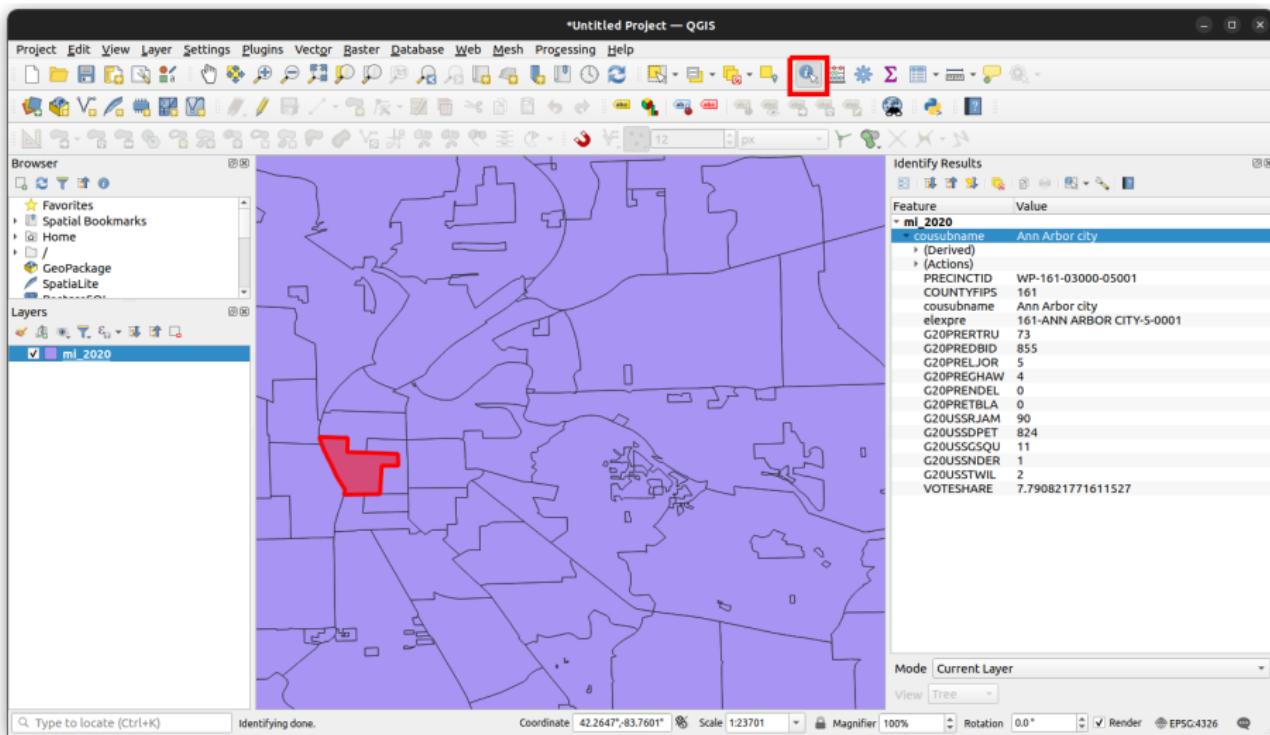
Navigate to folder with file, select `mi_2020.geojson`, click Open



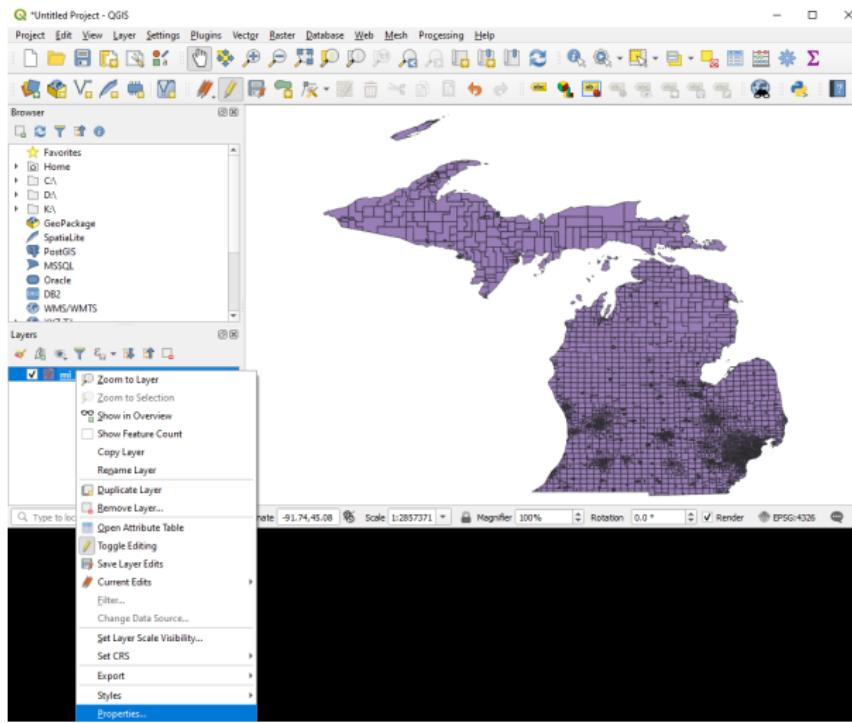
Click Add



You should see a map of Michigan's electoral precincts

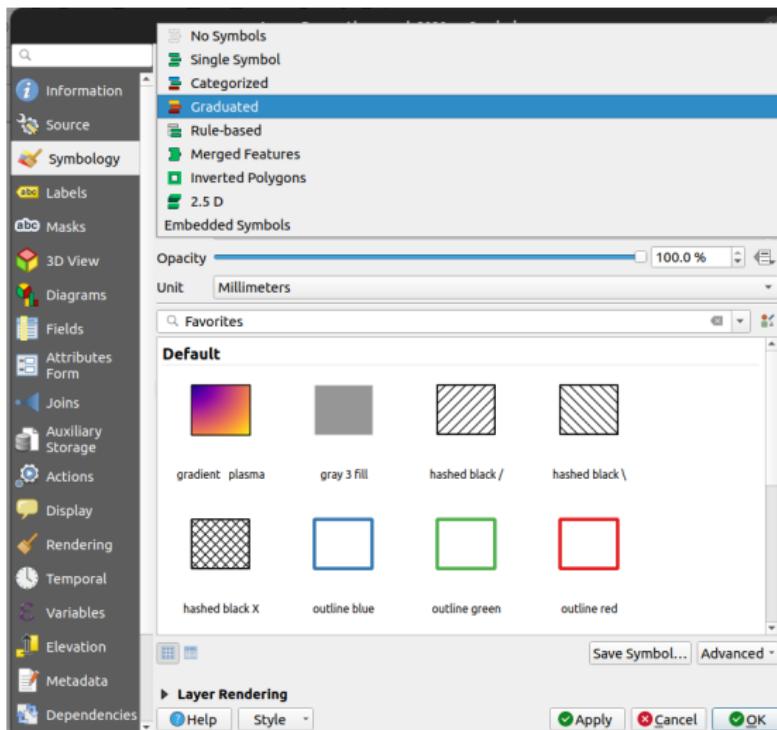


You can explore the vote tallies in each precinct by using the Identify Features tool (looks like an “i” in a circle). Using this tool, click on any polygon.

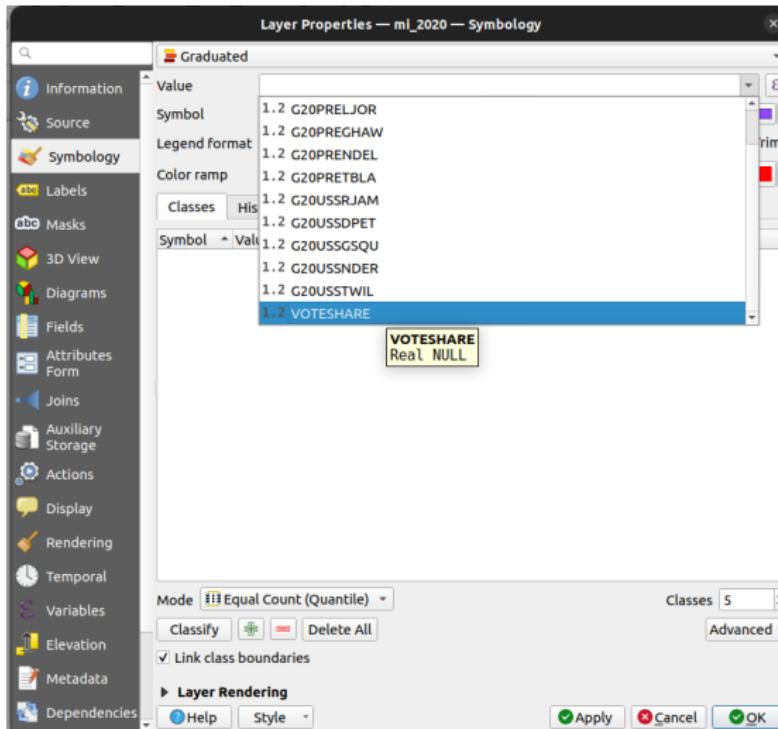


## 2. Color precincts by vote share:

right-click on layer's name (`mi_2020`), select Properties...



Select Symbology type → Graduated

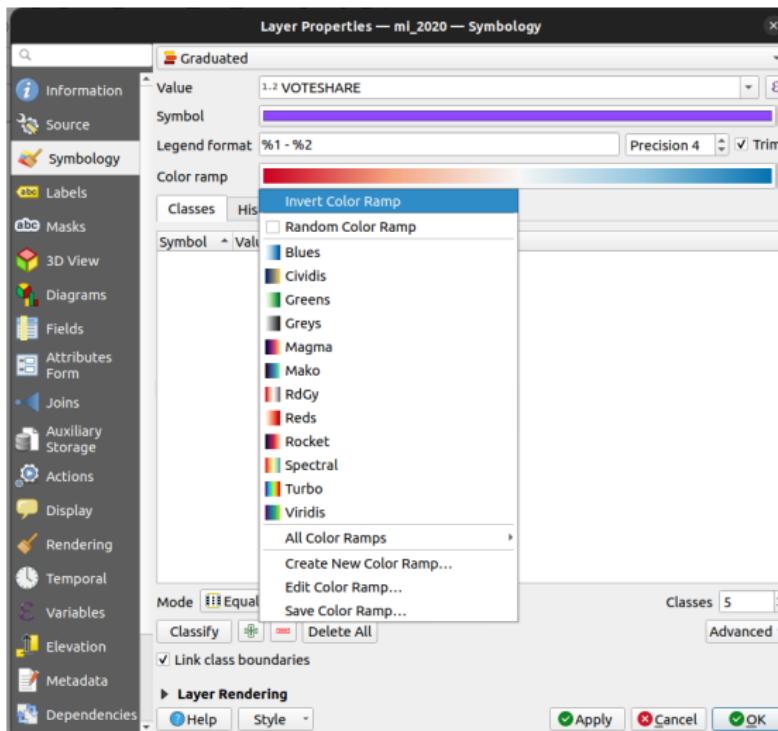


Set graphical parameters (select variable):  
Value → VOTESHARE (percent Trump)



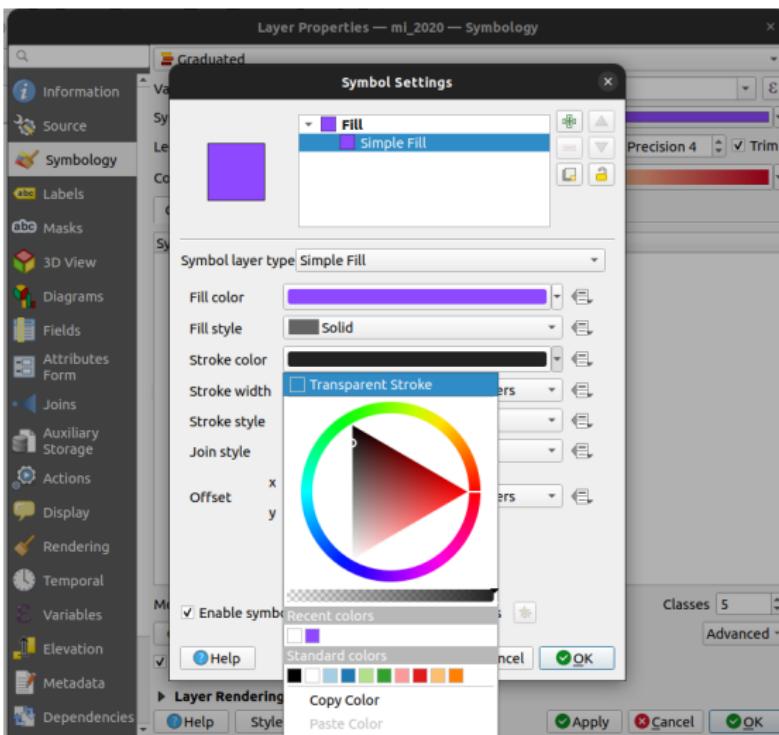
Set graphical parameters (select colors):

Color ramp → All Color Ramps → RdBu

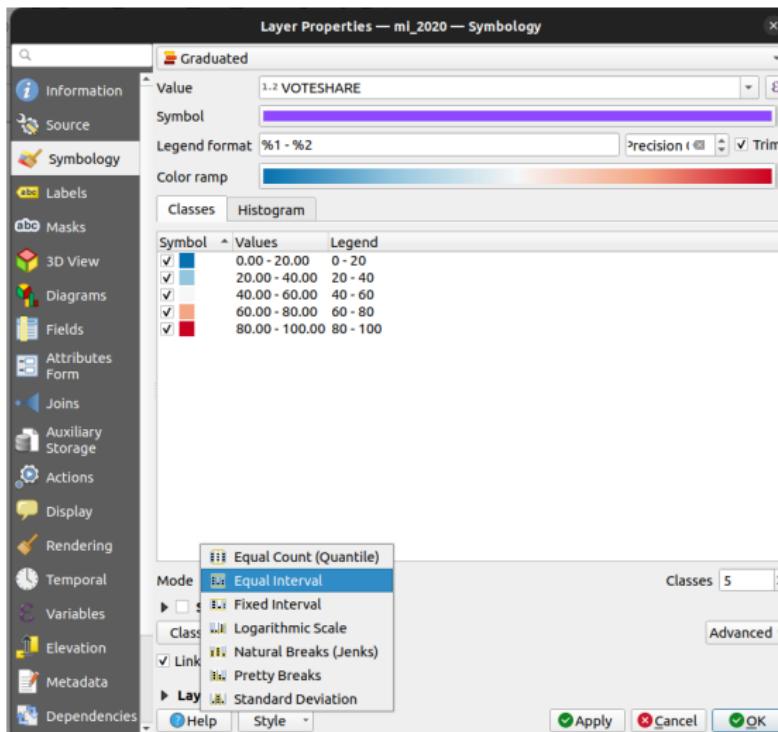


Set graphical parameters (select colors):

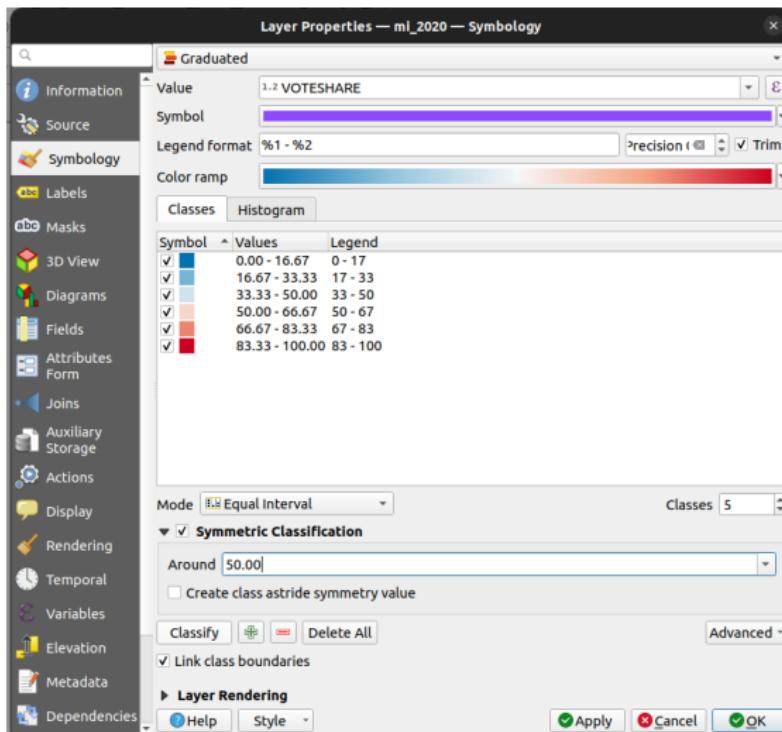
Color ramp → Invert Color Ramps (flip blue and red)



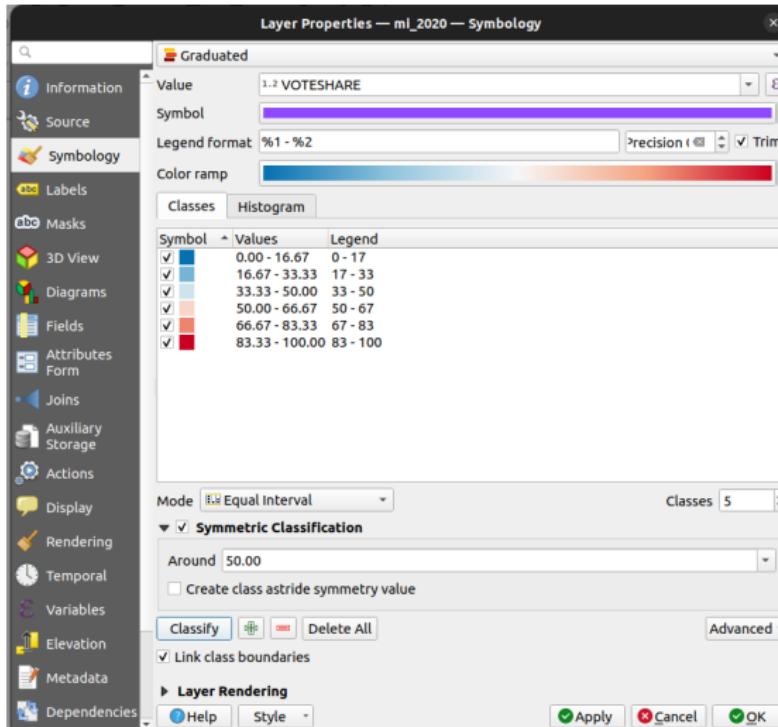
Set graphical parameters (make borders transparent):  
Symbol → Simple fill → Stroke color → Transparent stroke



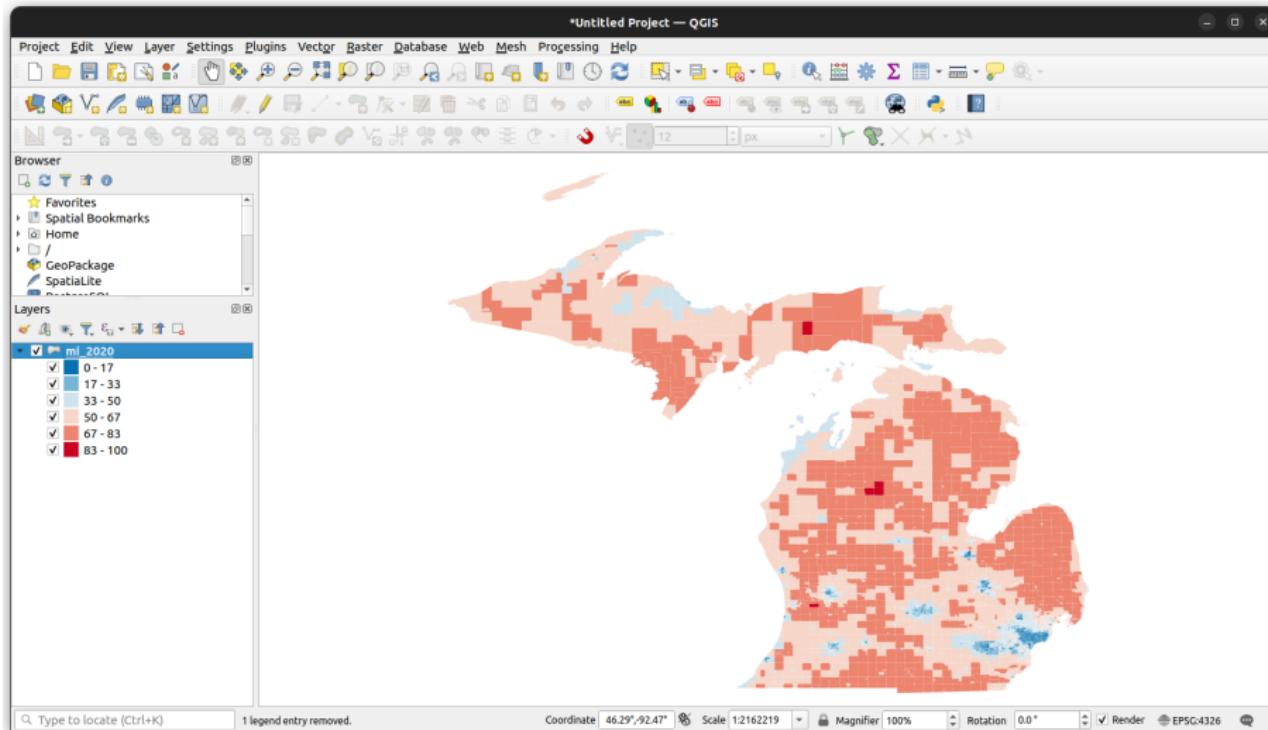
Set graphical parameters (select interval type):  
Mode → Equal interval



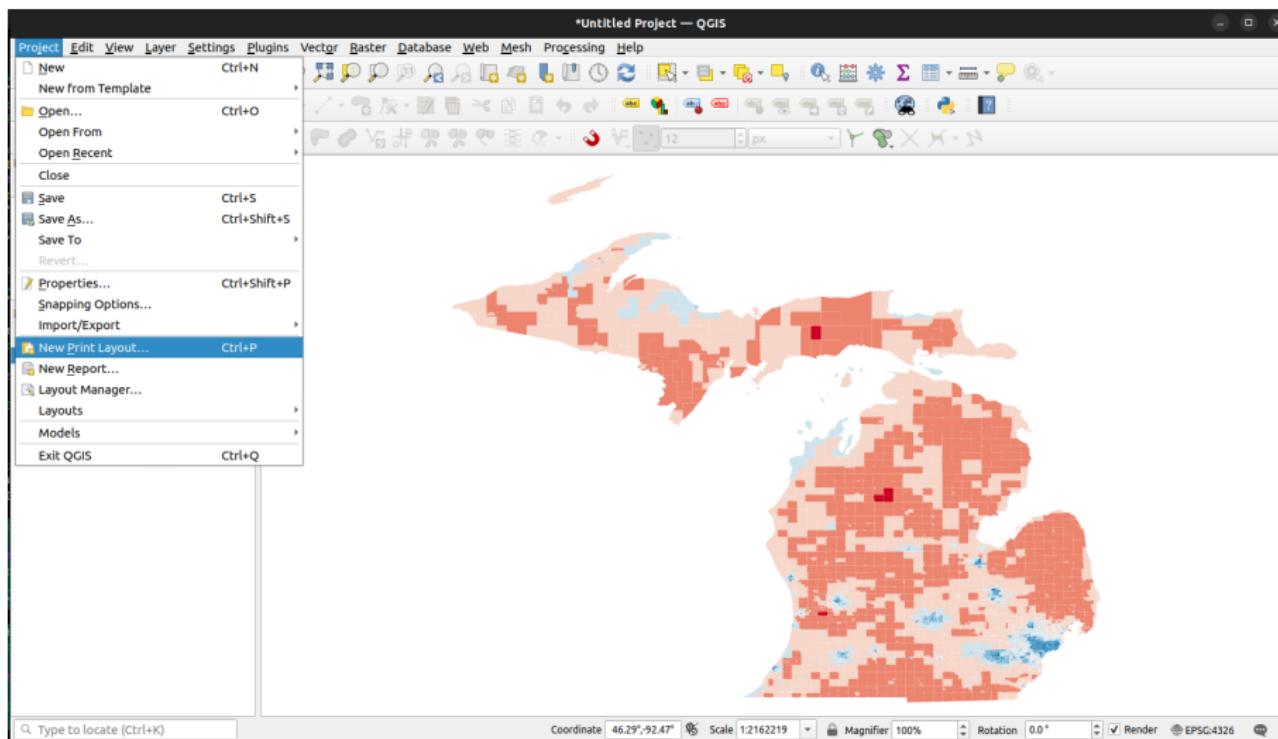
Set graphical parameters (center intervals at 50%):  
Symmetric classification → Around = 50.0.



Click Classify, then OK.

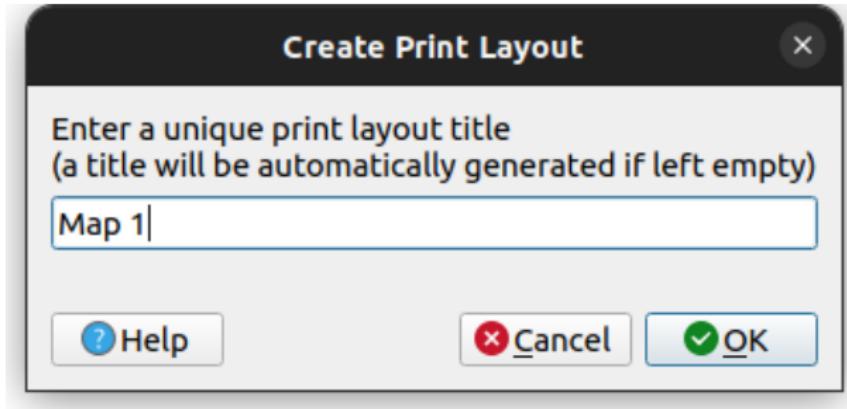


The precincts should now be colored on a **blue - red** gradient.

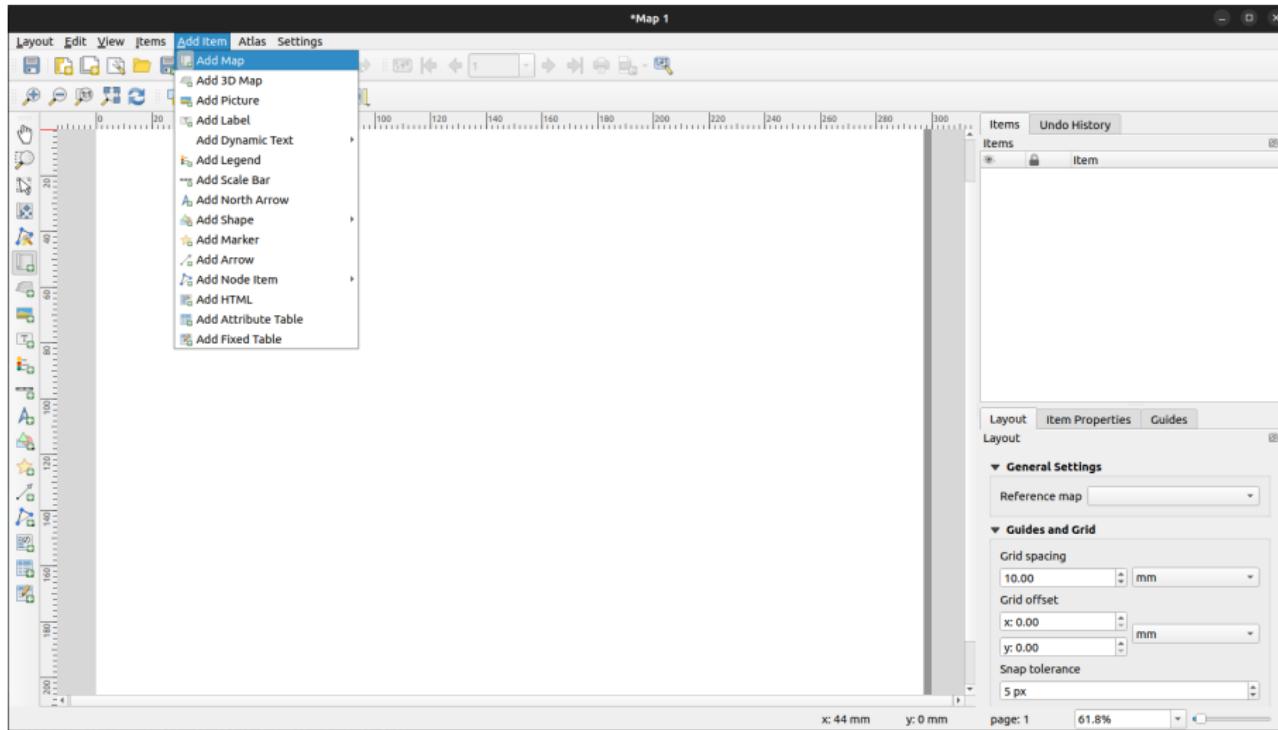


### 3. Save the map as an image

Project → New Print Layout...

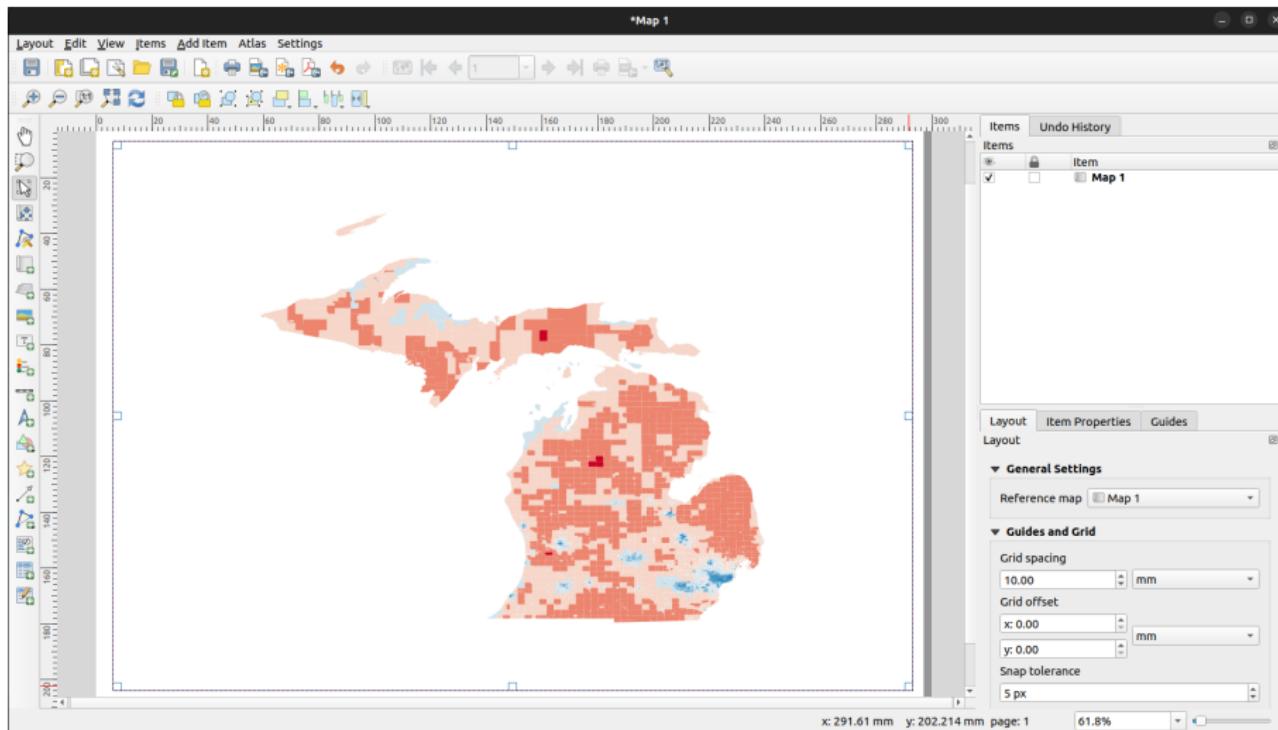


Name the print layout "Map 1"

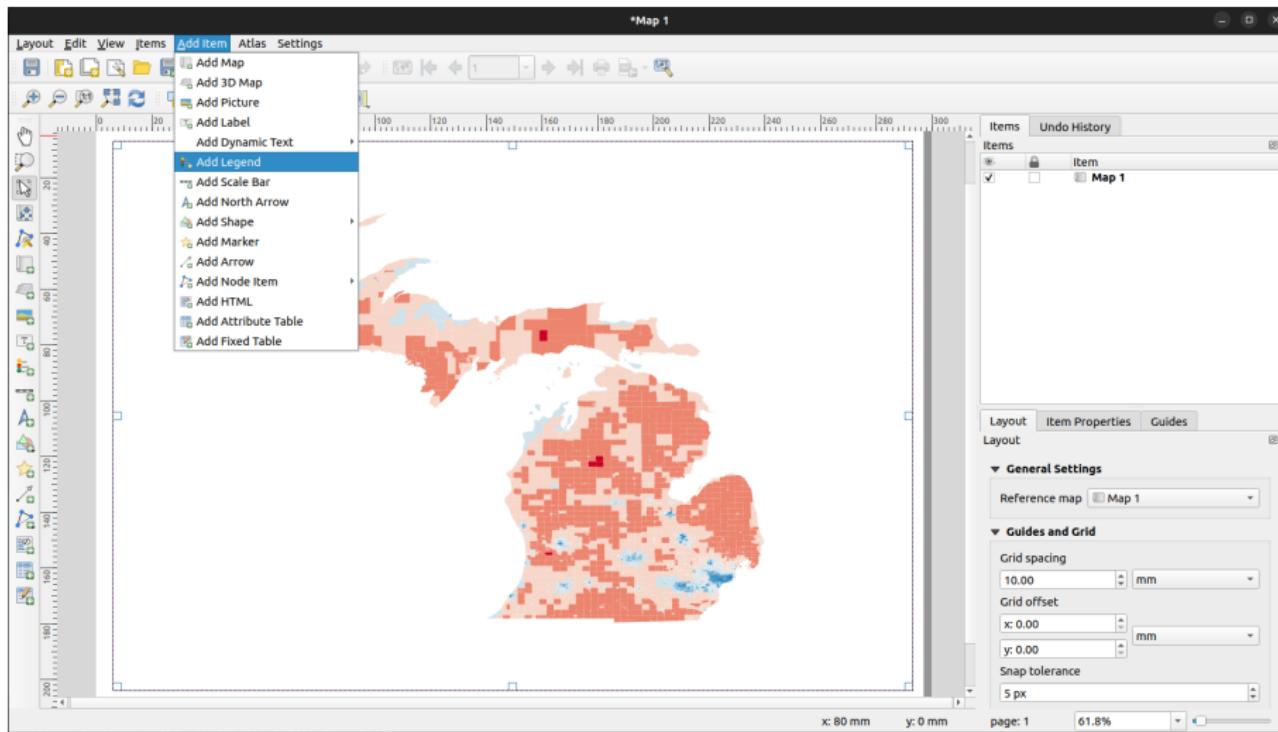


Add map:

Add item → Add map

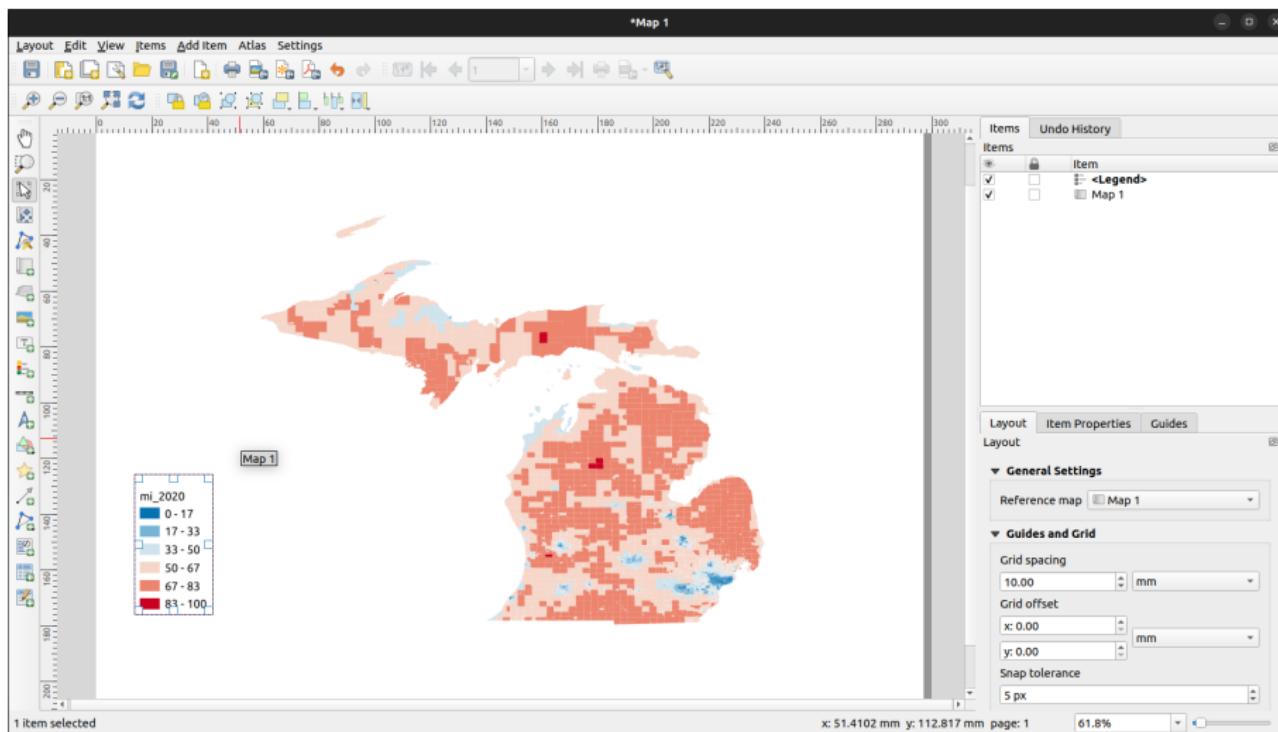


Add map:  
use mouse (click and drag) to place map on layout

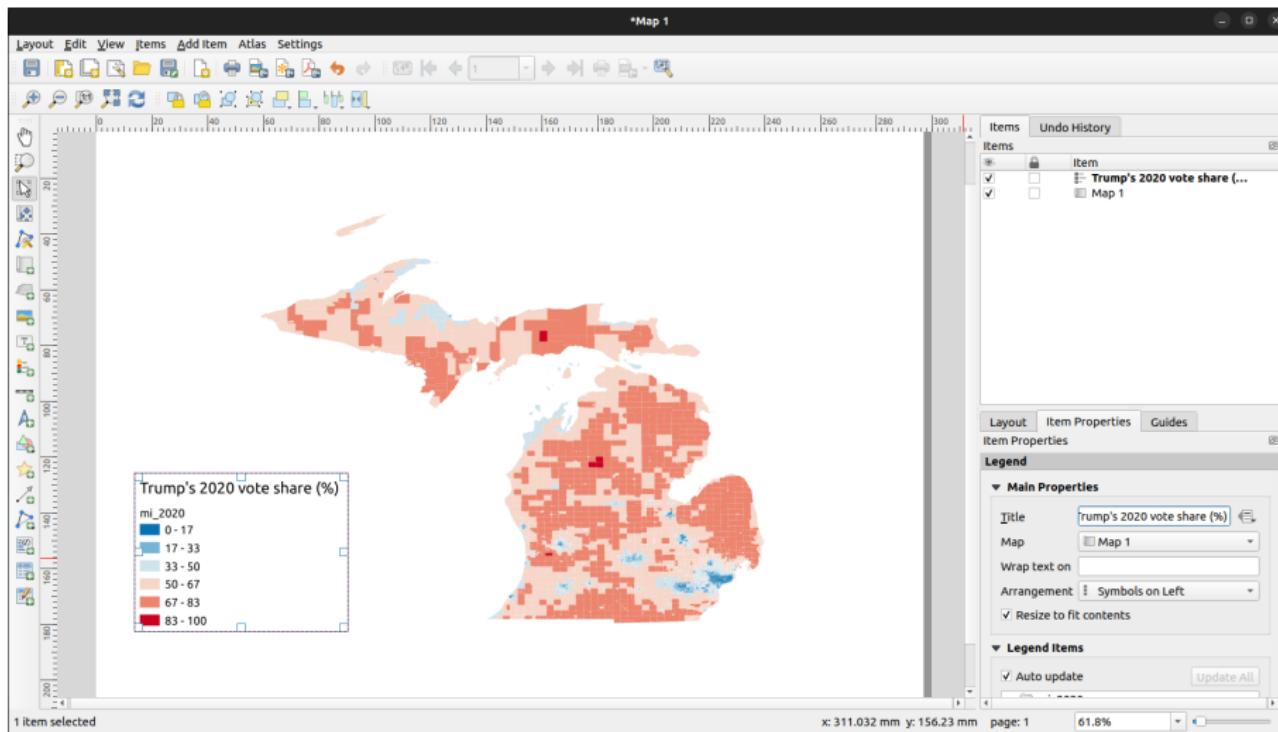


Add legend:

Add item → Add legend

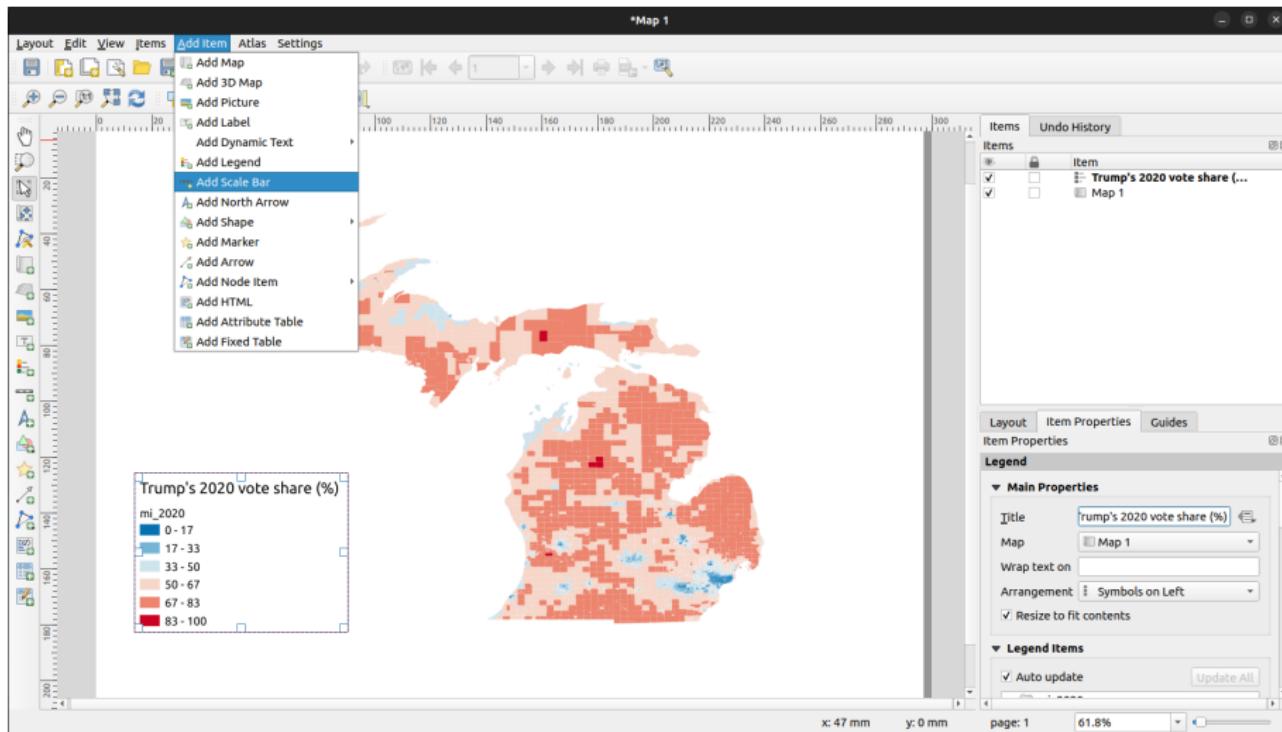


Add legend:  
a legend should appear, with subtitle mi\_2020



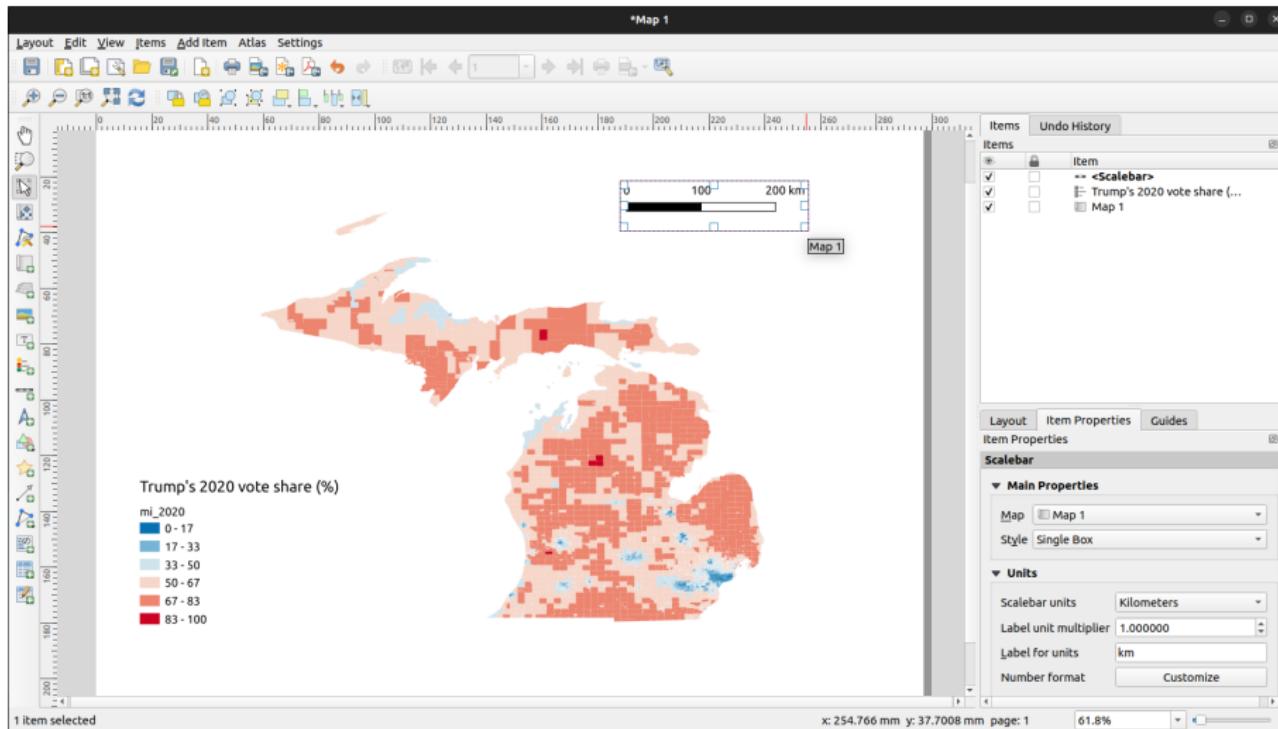
Add legend (change legend title):

Item Properties → Title = “Trump’s 2020 vote share (%)”

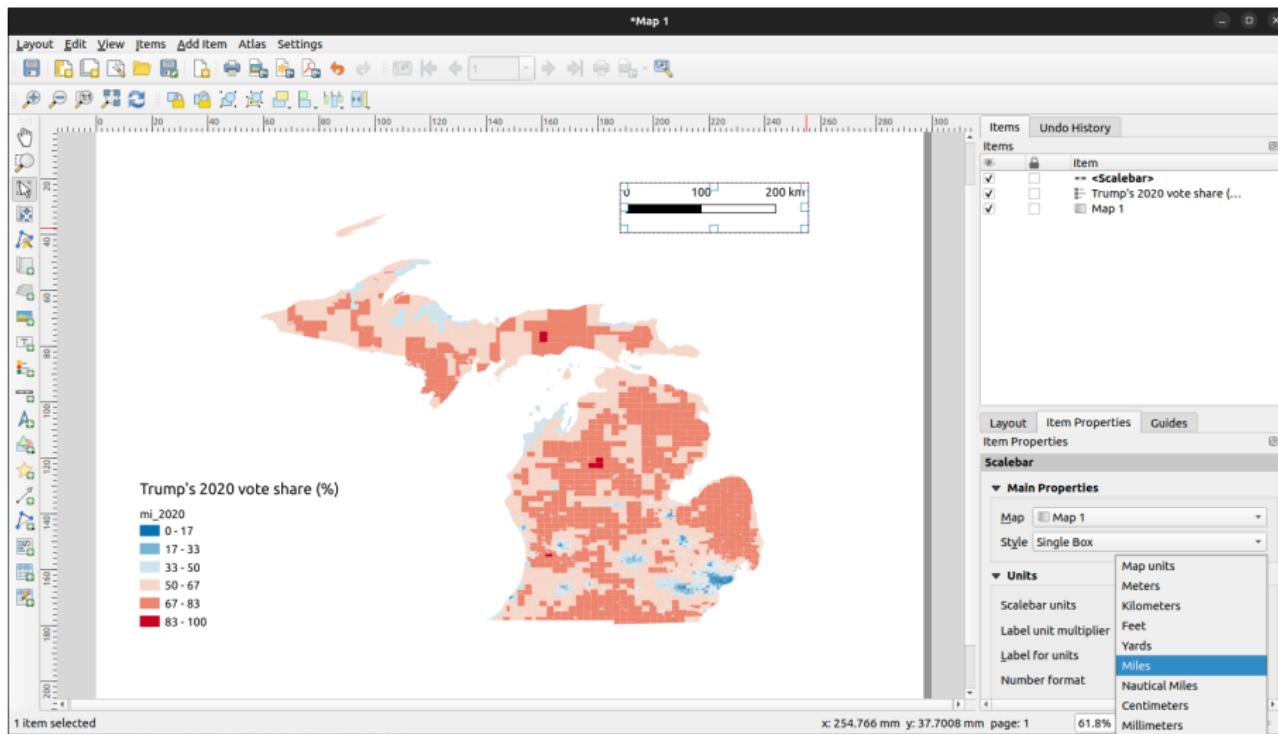


Add scale bar:

Add item → Add scale bar

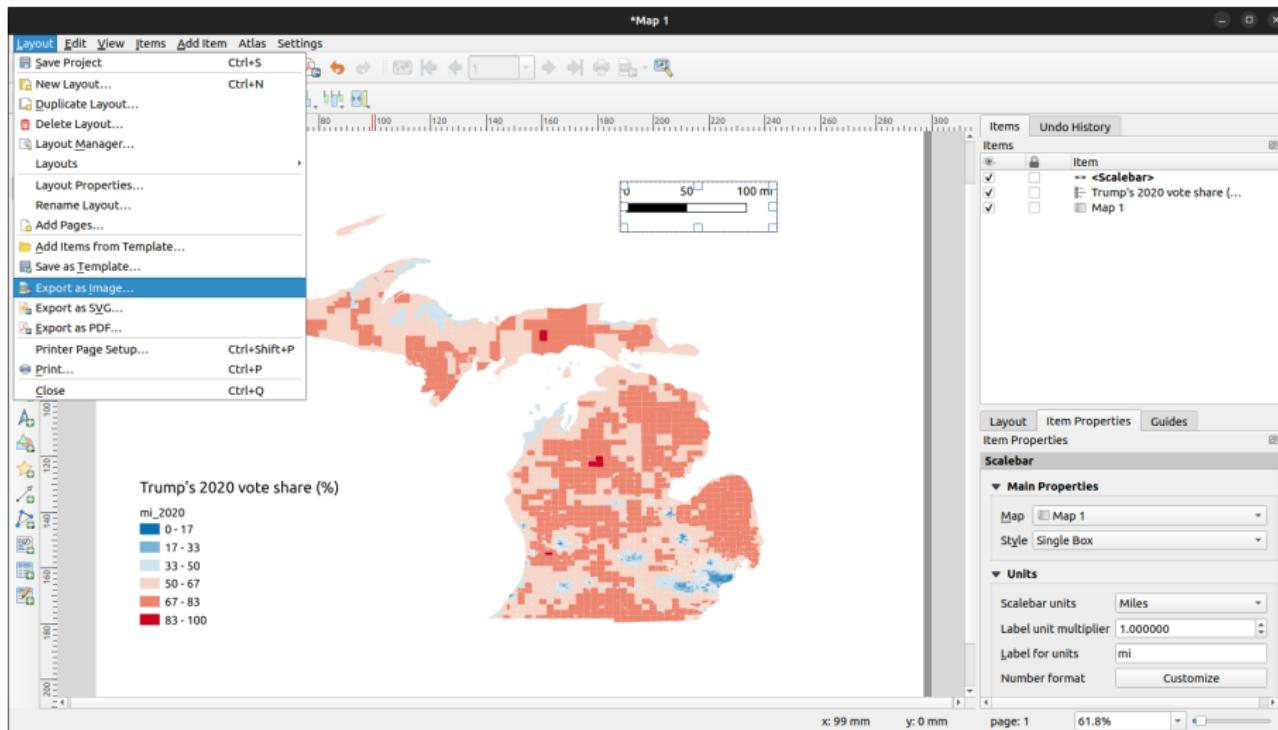


Add scale bar: a scale bar should appear, units are metric by default



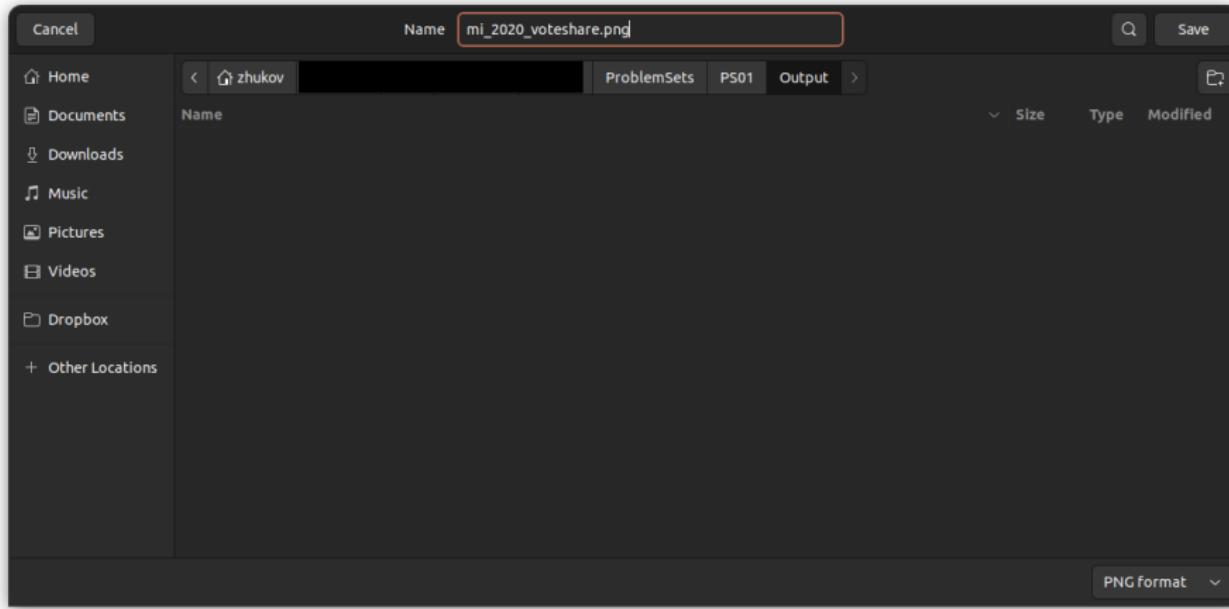
Add scale bar (change units to miles):

Item Properties → Units → Scalebar units = "Miles"

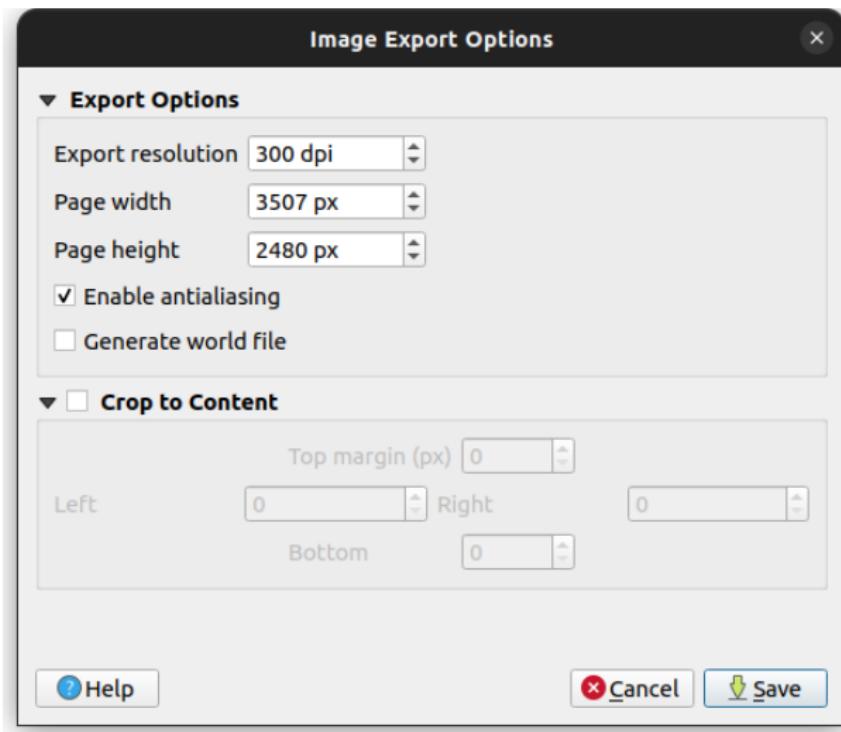


Save image to file:

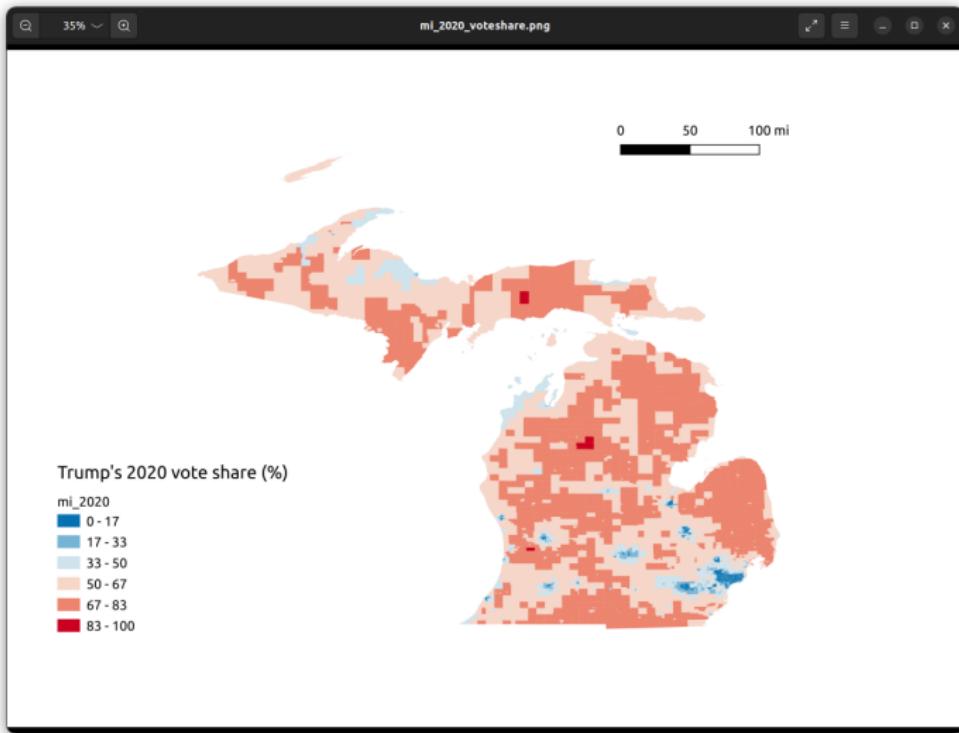
Layout → Export as image...



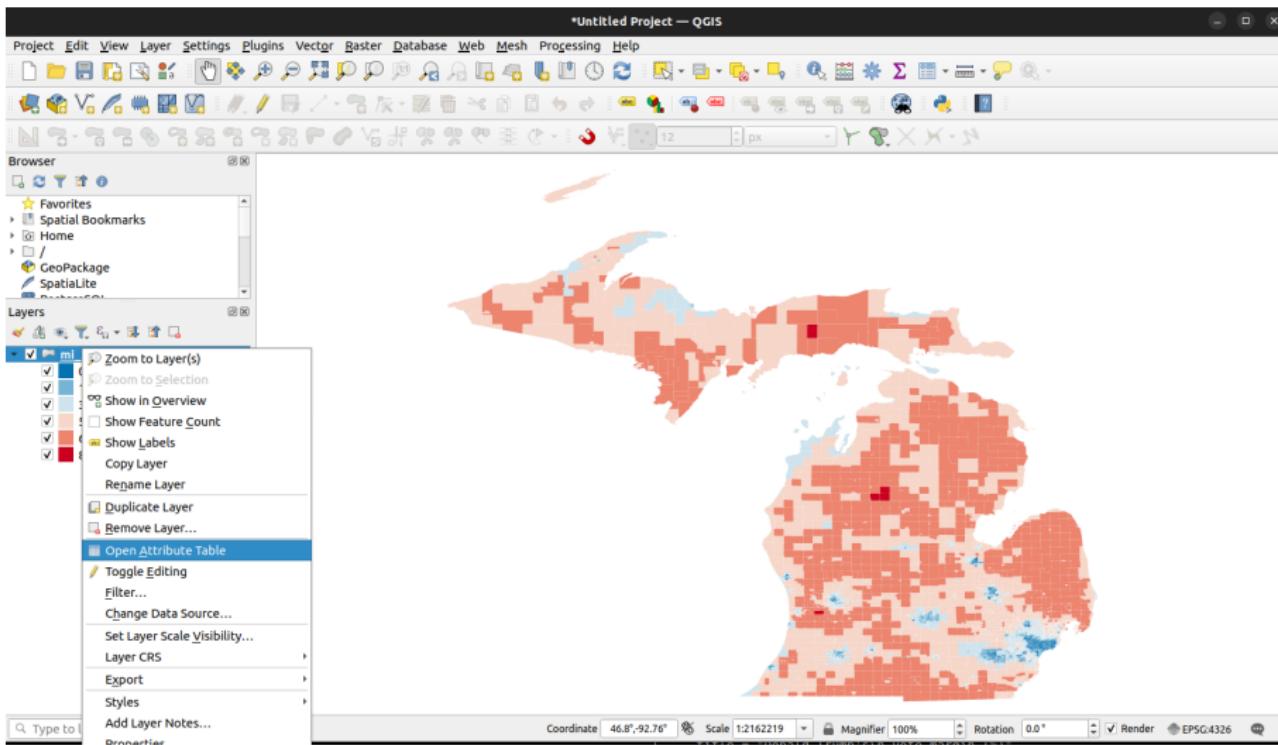
Select folder, name the file mi\_2020\_voteshare.png, click Save



Accept default settings, click Save



The image file should look something like this. Not pretty, but it's the first pancake.

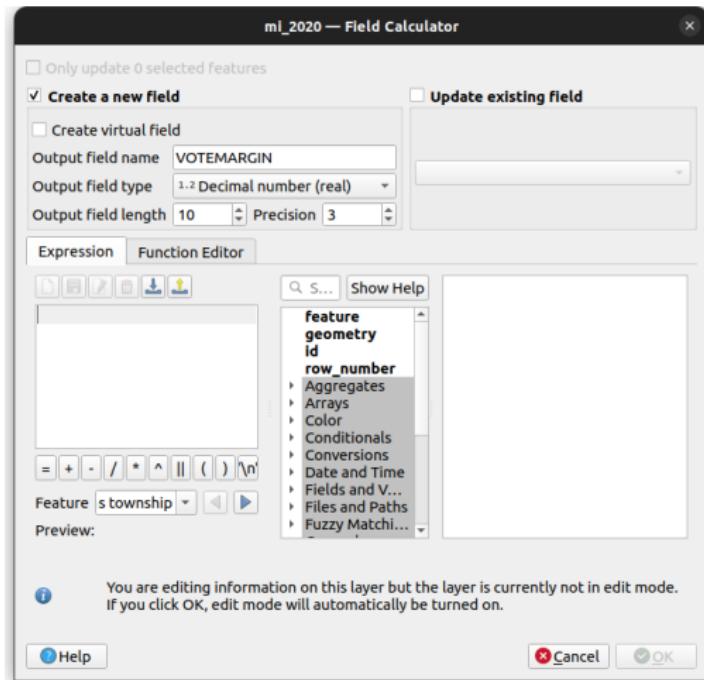


4. **Create new variable:** vote margin (percent Trump – percent Biden)  
Right click `mi_2020` layer → Open attribute table

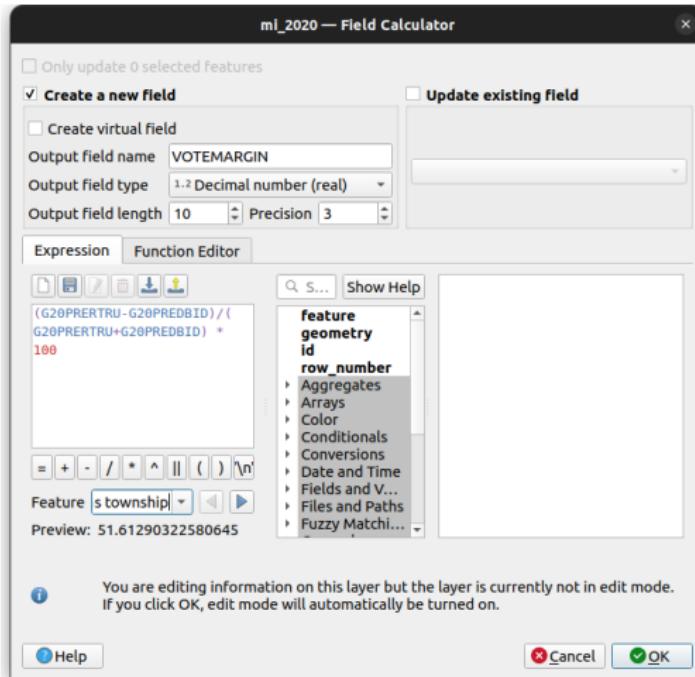
mi\_2020 — Features Total: 4751, Filtered: 4751, Selected: 0

	PRECINCTID	COUNTYFIPS	cousubname	elexpre	G20PREFTRL	Open field calculator (Ctrl+I)	G20PREGHAW	G20PRENDDEL	G20PRETBLA	G20USSRJAM	G20USSDPET	G20USSGSQU	G20USSNIDER	G20USSTWIL	VOTESHARE
1	WP-001-01...	001	Alcona tow...	001-ALCO...	564	248	3	2	0	2	539	267	4	2	3 68.864468...
2	WP-001-12...	001	Caledonia t...	001-CALED...	508	245	4	0	0	0	485	261	1	0	4 67.107001...
3	WP-001-19...	001	Curtis town...	001-CURT...	486	238	2	1	0	1	456	240	5	4	10 66.758241...
4	WP-001-34...	001	Greenbush ...	001-GREEN...	560	302	9	1	0	1	531	322	4	5	6 64.146620...
5	WP-001-35...	001	Gustin tow...	001-GUSTI...	317	112	9	0	0	0	306	122	1	0	6 72.374429...
6	WP-001-36...	001	Harrisville ...	001-HARRI...	136	127	2	2	0	1	137	127	1	1	2 50.746268...
7	WP-001-36...	001	Harrisville t...	001-HARRI...	582	241	5	1	0	3	562	253	1	1	3 69.951923...
8	WP-001-37...	001	Hawes tow...	001-HAWE...	508	199	7	0	0	1	486	213	4	1	5 71.048951...
9	WP-001-37...	001	Haynes tow...	001-HAYNE...	366	167	2	2	0	1	361	171	3	0	1 68.029739...
10	WP-001-53...	001	Mikado to...	001-MIKAD...	421	122	5	1	0	0	382	147	5	0	6 76.684881...
11	WP-001-54...	001	Millen tow...	001-MILLE...	184	80	1	1	0	1	165	95	3	1	2 68.913857...
12	WP-001-54...	001	Mitchell to...	001-MITCH...	216	61	1	0	0	1	204	66	2	0	2 77.419354...
13	WP-003-04...	003	Au Train to...	003-AU TR...	472	264	7	0	0	2	479	260	1	0	3 63.355704...
14	WP-003-11...	003	Burt towns...	003-BURT ...	198	149	3	1	0	0	196	150	1	0	5 56.410256...
15	WP-003-33...	003	Grand Islan...	003-GRAN...	17	13	0	0	0	0	15	14	0	0	0 56.666666...
16	WP-003-47...	003	Limestone ...	003-LIMES...	148	109	1	1	1	0	147	109	2	1	1 56.923076...

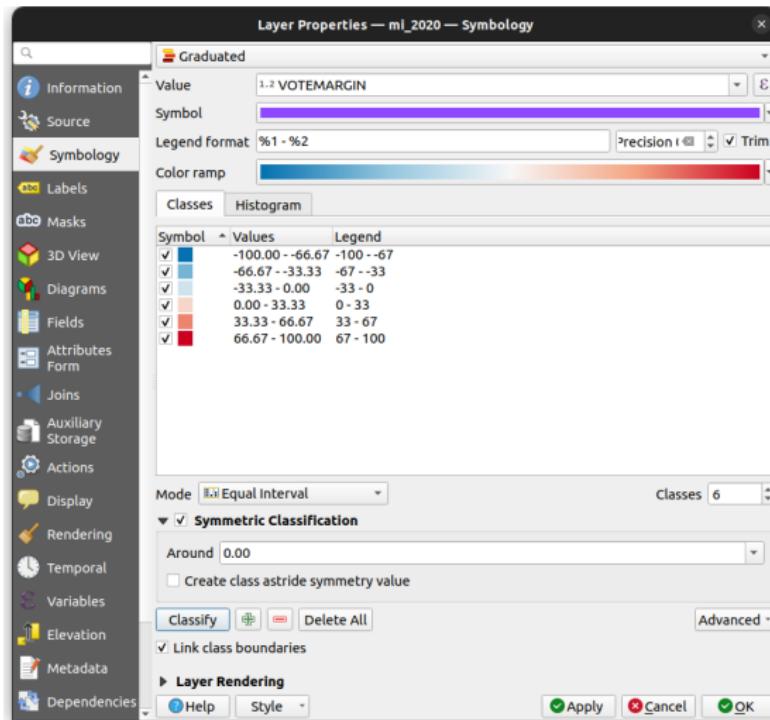
On top of spreadsheet, click Open field calculator button



- Create New Field → Output field name = VOTEMARGIN
- Output field type = "Decimal number (real)"

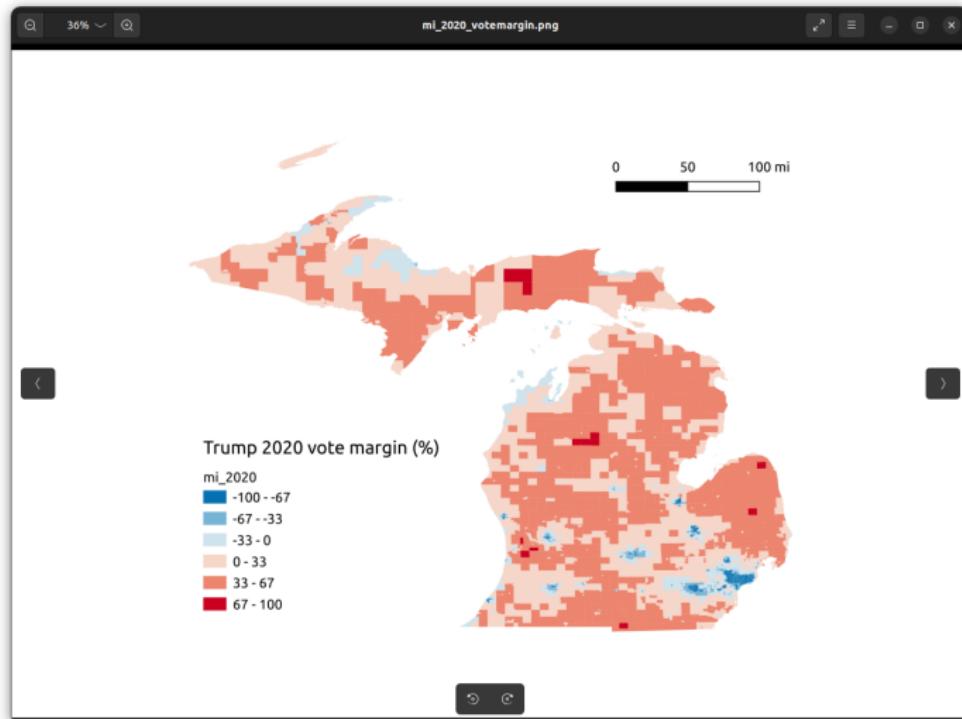


Expression:  $(G20PRERTRU-G20PREDBID)/(G20PRERTRU+G20PREDBID)*100$   
Click OK



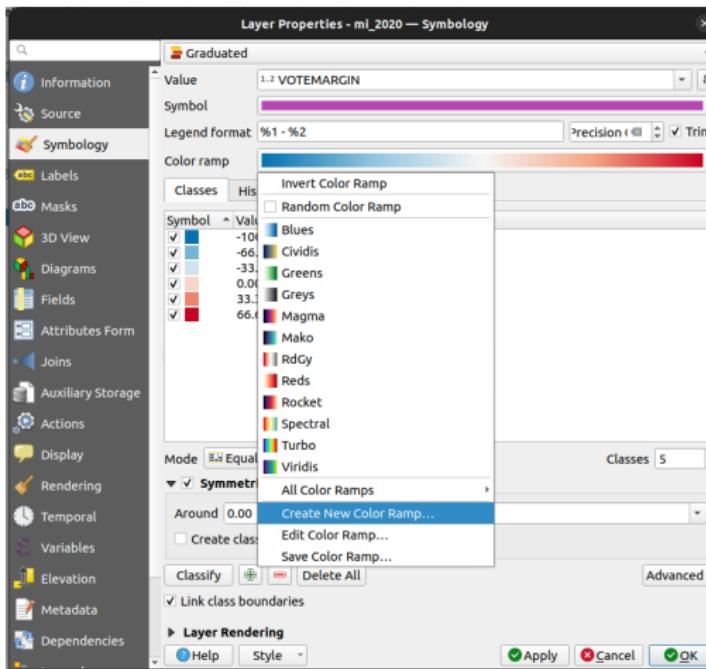
Repeat the same steps as before:

Color precincts by vote margin, symmetric classification Around = 0.00



Repeat the same steps as before:

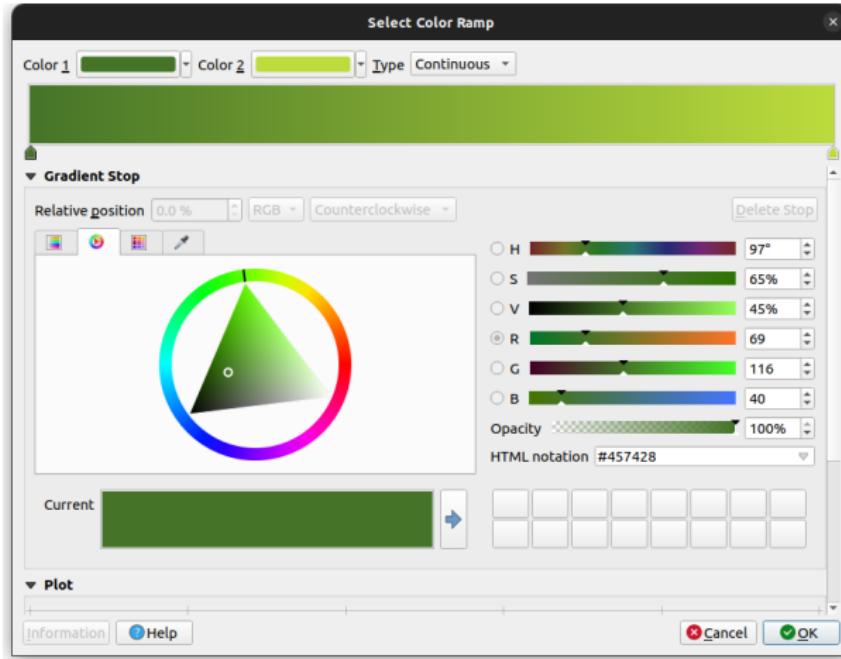
Save map as image (mi\_2020\_votemargin.png)



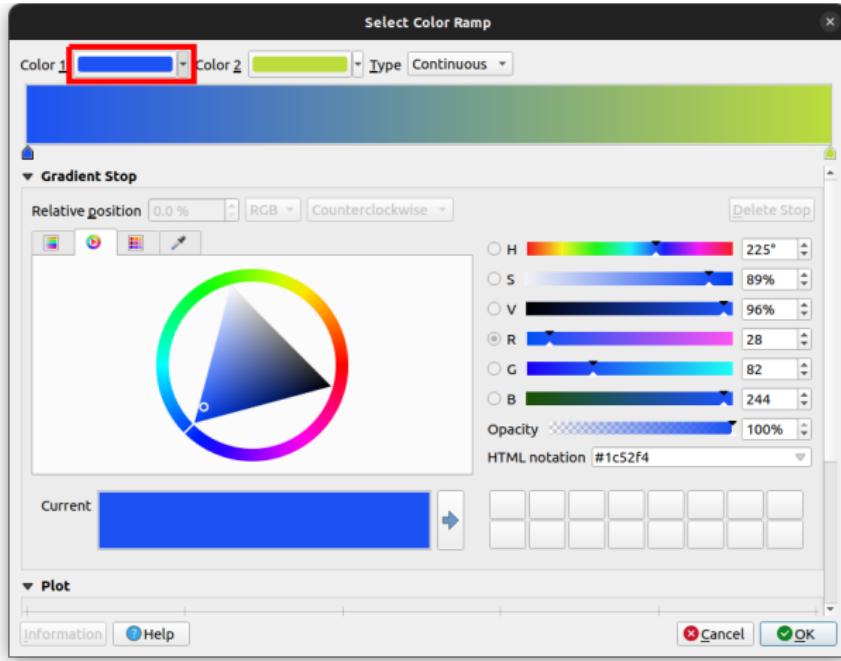
*Optional:* to make middle color purple (not white), go to Color ramp → Create New Color Ramp... in the Symbology tab



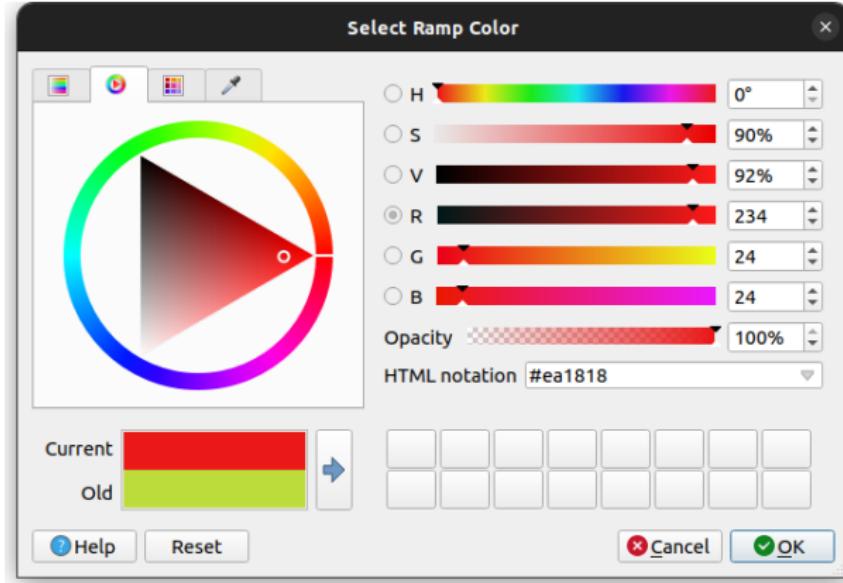
Select Gradient as color ramp type



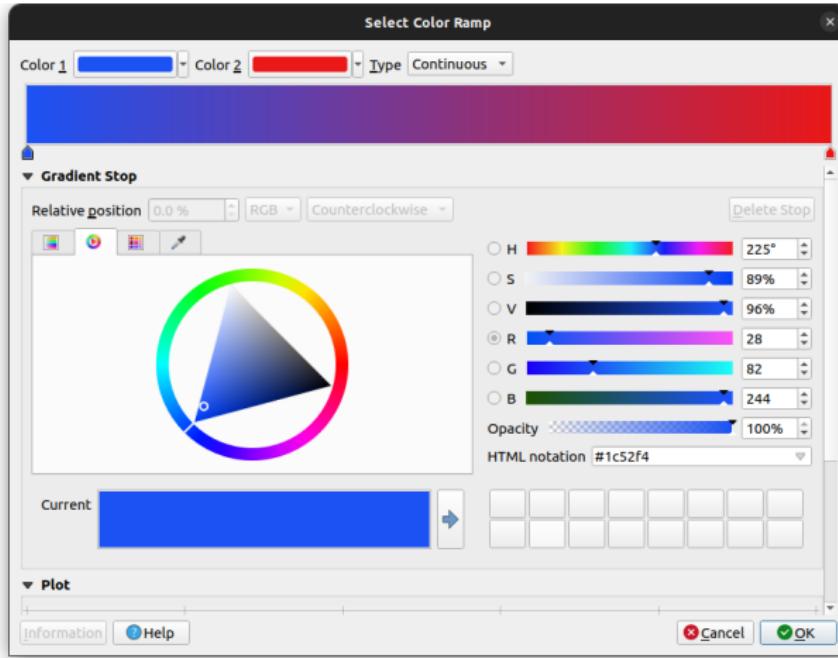
This will open a new screen, where you can select the colors you want



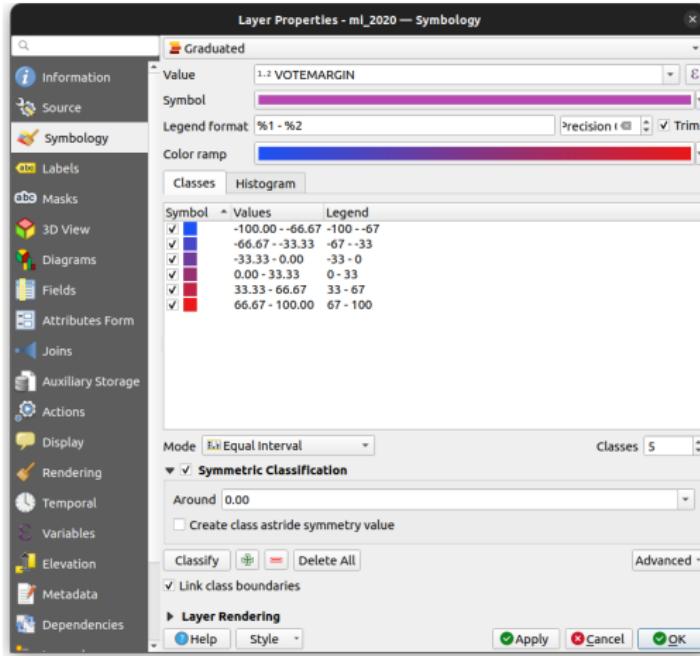
Click on Color 1 and select a blue color



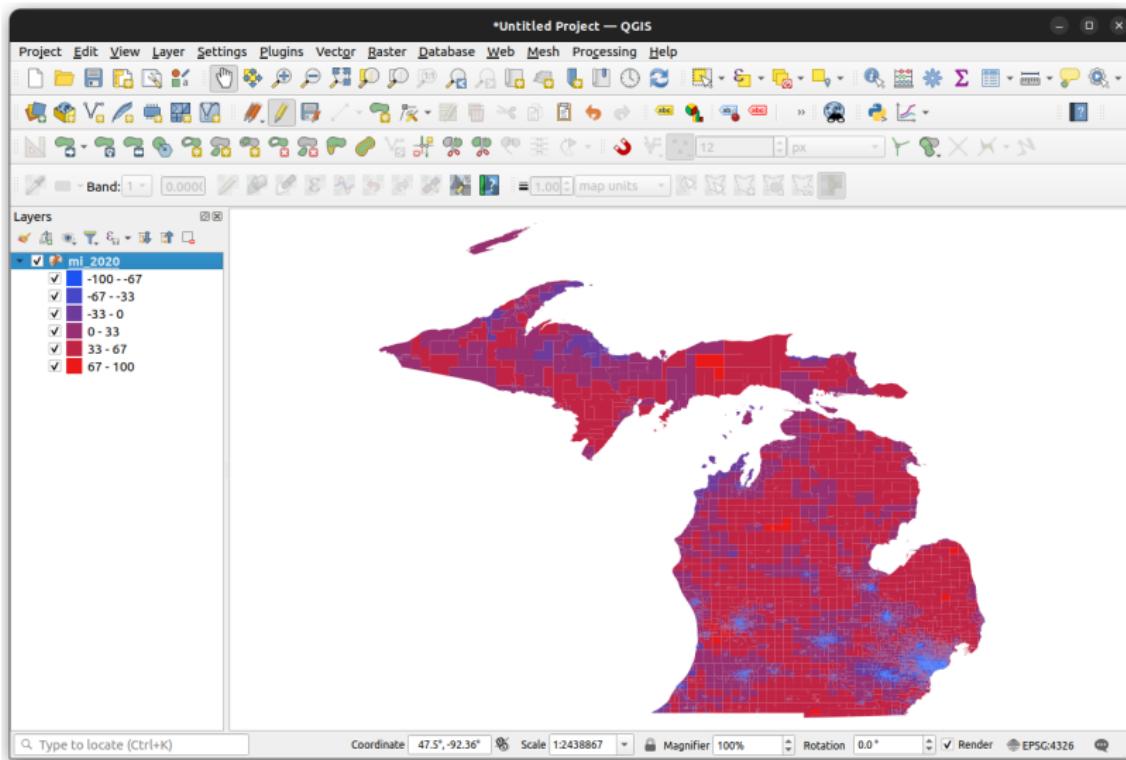
Click on Color 2 and select a red color



The middle color should now be purple. Click OK



The color classifications in the Symbology tab should automatically update. Click OK again



Closely-contested precincts should now appear as purple, not white

## Problem Set

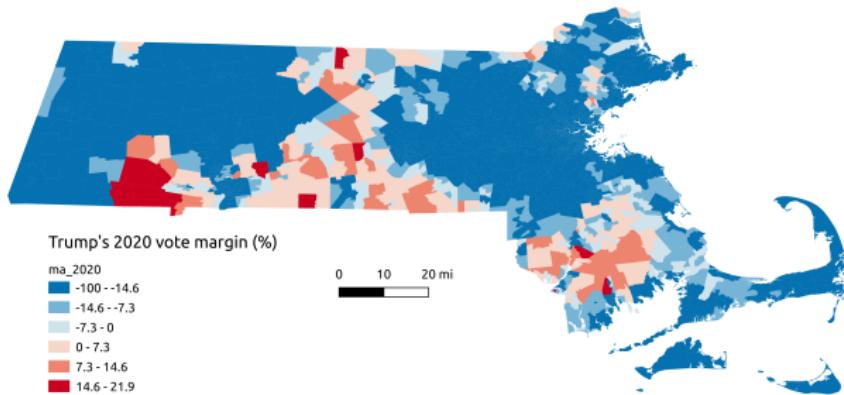


Figure 3: Can you make this map?

**Your assignment** (if using QGIS):

create the same kind of map for Massachusetts, using dataset `ma_2020.geojson`

- precincts colored by `VOTEMARGIN` (new variable)
- color ramp could be blue-white-red (shown here) or blue-purple-red
- name the file `ma_2020_votemargin.png`
- upload map to Canvas (by next Monday)

R

## Introduction and Demo

## Quick introduction to R

R is a programming language, which means you need to type commands, rather than pointing-and-clicking (unlike QGIS)

R scripts are plain text files with extension .R

- to create a new script in RStudio, go to **File menu → New File → R Script**
- ... or open an existing script with **File → Open File...**
- save your script with **File → Save or File → Save As...**  
(remember to save it with extension '.R')

The advantage of running scripts is that

- it's faster (once you get the hang of it),
- more efficient, and
- you get the same result every time

To run a single line of code, type a command, place your cursor at the line and hit **Ctrl+Enter** (Windows, Linux) or **Command+Enter** (MacOS)

```
print("Hello world!")
```

```
## [1] "Hello world!"
```

Let's try some arithmetic

```
2+2
```

```
## [1] 4
```

```
2-2
```

```
## [1] 0
```

```
2*2
```

```
## [1] 4
```

```
2/2
```

```
## [1] 1
```

## Basic syntax

To create a vector, we use

- assignment operators = or <-
- grouping operator c()

```
x = c(1,2,3,4,5)
x
## [1] 1 2 3 4 5

x <- c(1,2,3,4,5) # Equivalent to above
x
## [1] 1 2 3 4 5

y = x^2
y
## [1]  1   4   9  16  25
```

## Basic syntax (cont'd)

Combine vectors into a dataset with the `data.frame()` command

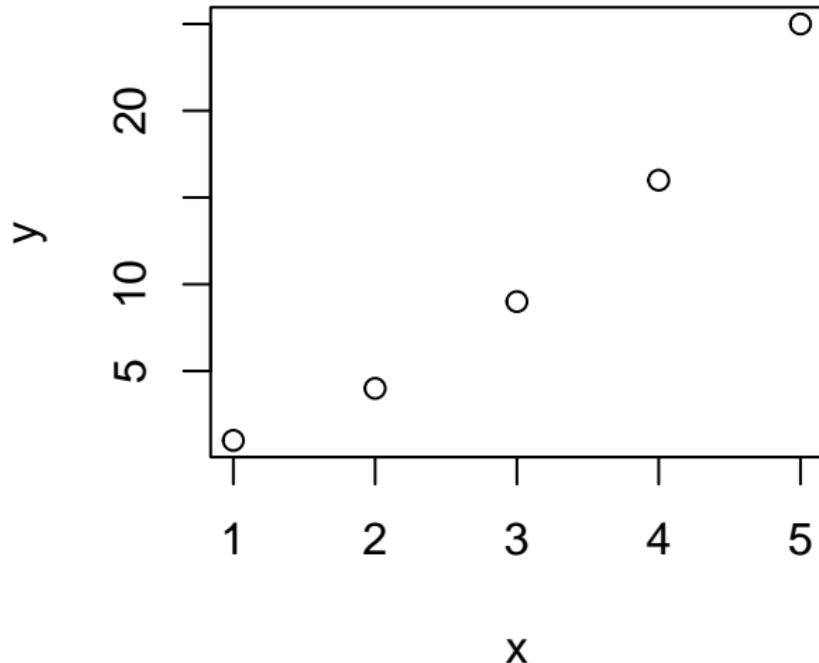
```
my_dataset = data.frame(x=x,y=y)
summary(my_dataset)
```

```
##           x             y
##   Min.   :1   Min.   : 1
##   1st Qu.:2   1st Qu.: 4
##   Median :3   Median : 9
##   Mean    :3   Mean    :11
##   3rd Qu.:4   3rd Qu.:16
##   Max.    :5   Max.    :25
```

## Basic plotting

Create a basic scatterplot with the `plot()` function

```
plot(x,y)
```



## Getting help

To access the *help file* for any function, type ? before the function's name

```
?c  
?data.frame  
?summary  
?plot
```

There is also an abundance of online help forums for R users:

- [stackoverflow.com](http://stackoverflow.com)
- [stats.stackexchange.com](http://stats.stackexchange.com)

## Loading external packages

For this exercise, we will need two external packages:

- **sf** ("simple features", to handle spatial vector data)
- **PlotTools** (to customize plot legends)

We install packages with `install.packages()` and load them with `library()`

```
install.packages("sf") # (first time only)
install.packages("PlotTools") # (first time only)
library(sf)
library(PlotTools)
```

## Setting working directory

We should always set a *working directory*, using the `setwd()` function.

The working directory is a folder on your hard drive, where you stored the data for this exercise, and where you'll be saving maps.

You can find the path of a folder through Right-click → Get Info (MacOS) or Right-click → Properties (Windows).

On MacOS and Linux:

```
setwd("/home/username/Documents/SEST6577")
```

On Windows:

```
setwd("C:/Documents/SEST6577")
```

To find out your current working directory:

```
getwd()
```

## Loading spatial vector data

Load the data through the `read_sf()` function from the `sf` package

```
mi_2020 = sf::read_sf(dsn = "Data/mi_2020.geojson")
```

Let's take a look at the first 5 rows of mi\_2020, using `print(mi_2020,n=5)`

```
print(mi_2020,n=5)
```

```
## Simple feature collection with 4751 features and 16 fields
## Geometry type: MULTIPOLYGON
## Dimension: XY
## Bounding box: xmin: -90.41829 ymin: 41.69613 xmax: -82.41348 ymax: 48.26269
## Geodetic CRS: WGS 84
## # A tibble: 4,751 x 17
##   PRECINCTID COUNTYFIPS couesubname elexpre G20PRERTRU G20PREDBID G20PRELJOR
##   <chr>        <chr>      <chr>     <chr>      <dbl>      <dbl>      <dbl>
## 1 WP-001-01040-0- 001    Alcona to- 001-AL-    564       248       3
## 2 WP-001-12460-0- 001    Caledonia- 001-CA-    508       245       4
## 3 WP-001-19320-0- 001    Curtis to- 001-CU-    486       238       2
## 4 WP-001-34820-0- 001    Greenbush- 001-GR-    560       302       9
## 5 WP-001-35740-0- 001    Gustin to- 001-GU-    317       112       9
## # i 4,746 more rows
## # i 10 more variables: G20PREGHAW <dbl>, G20PRENDDEL <dbl>, G20PRETBLA <dbl>,
## #   G20USSRJAM <dbl>, G20USSDPET <dbl>, G20USSGSQU <dbl>, G20USSNDER <dbl>,
## #   G20USSTWIL <dbl>, VOTESHARE <dbl>, geometry <MULTIPOLYGON [°]>
```

This tells us:

- the object class (**Simple feature collection**)
- the object's geometry type (**MULTIPOLYGON**) and spatial extent
- its projection attributes (**WGS 84**)... more on this later
- and a preview of the attribute table (**A tibble: 4,751 x 17**)

## Visualizing spatial vector data

Let's visualize the study region with `plot(mi_2020["geometry"])`

```
plot(mi_2020["geometry"])
```



Now let's plot some attributes...

For a **categorical variable** (win/lose), visualization is simple...

1. Create a vector of colors, where each precinct Trump won is coded **red** and every each precinct won by Biden is **blue**

```
cols = ifelse(mi_2020$G20PRERTRU>mi_2020$G20PREDBID, "red", "blue")
plot(mi_2020[["geometry"]], col=cols)
```

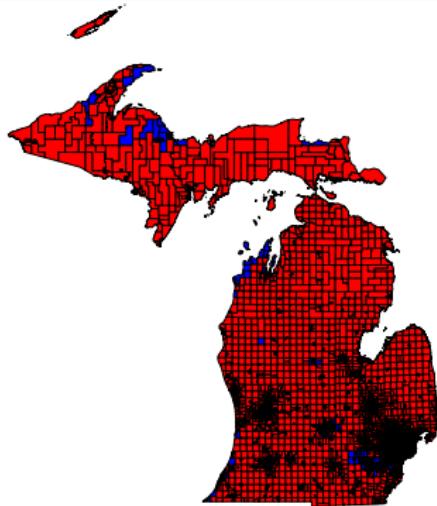
2. Use the resulting color vector with the `plot(col=...)` command.

```
plot(mi_2020[["geometry"]], col=cols)
```



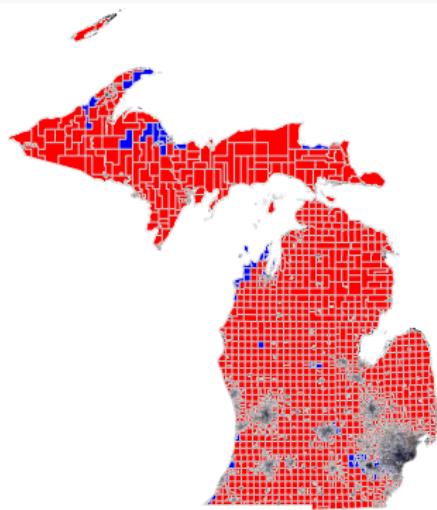
Change the border's thickness by changing lwd parameter

```
plot(mi_2020["geometry"], col=cols, lwd=.1)
```



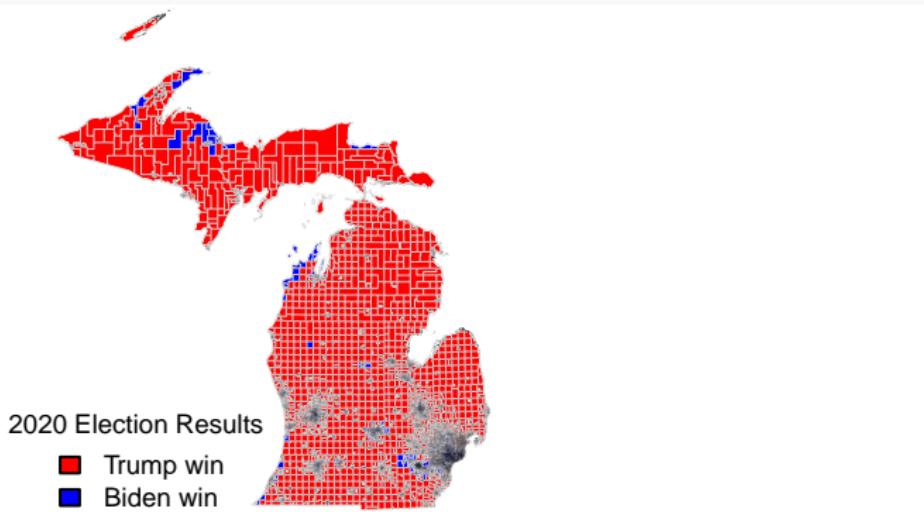
Make border semi-transparent through alpha parameter in `rgb`

```
plot(mi_2020[\"geometry\"],col=cols,lwd=.1,  
      border=rgb(red = 0,green = 0,blue = 0,alpha = .5))
```



### 3. Add a map legend with legend() command

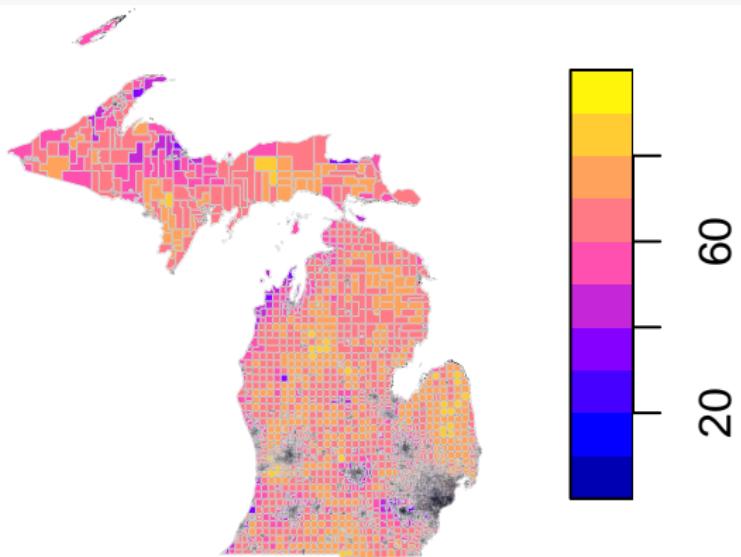
```
legend(  
  x = "bottomleft",  
  title = "2020 Election Results",  
  fill = c("red","blue"),  
  legend =c("Trump win","Biden win")  
)
```



Visualizing a **continuous variable** (e.g. vote share) is a little more tricky.

A relatively simple approach is to accept the default color palette like this:

```
plot(mi_2020["VOTESHARE"])
```



Or we can create a **custom color palette** (e.g. a red - blue gradient).

1. Let's set the number of breaks (e.g. 100)

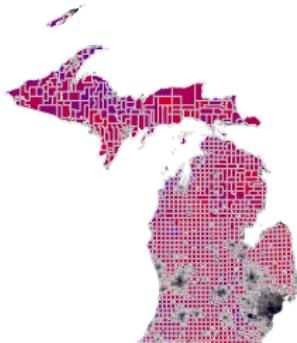
```
breaks = seq(0,100,by=1)
```

2. Create an RGB color ramp for the VOTESHARE variable

```
ramp = findInterval(mi_2020$VOTESHARE,breaks)
cols = rgb(ramp/length(breaks),0,(length(breaks)-ramp)/length(breaks))
```

3. Use this vector of colors in the plot(col=...) command

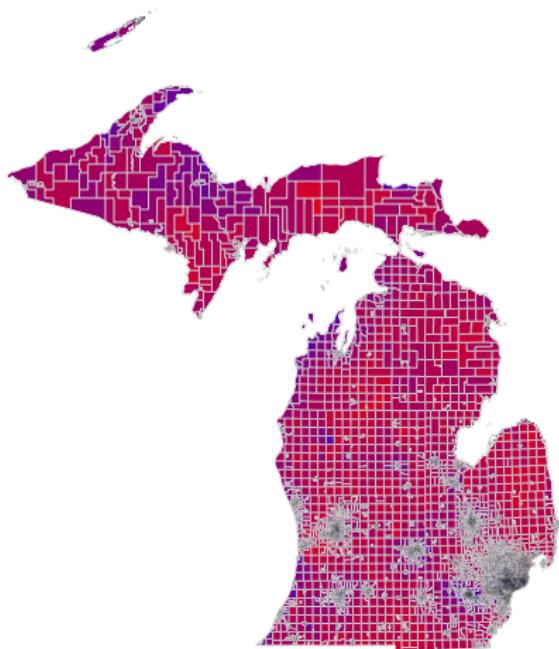
```
plot(mi_2020[ "VOTESHARE"],col=cols)
```



Add a title to the plot, with `main` parameter

```
plot(mi_2020["VOTESHARE"], col=cols,  
     main="Michigan 2020 Presidential Election Results")
```

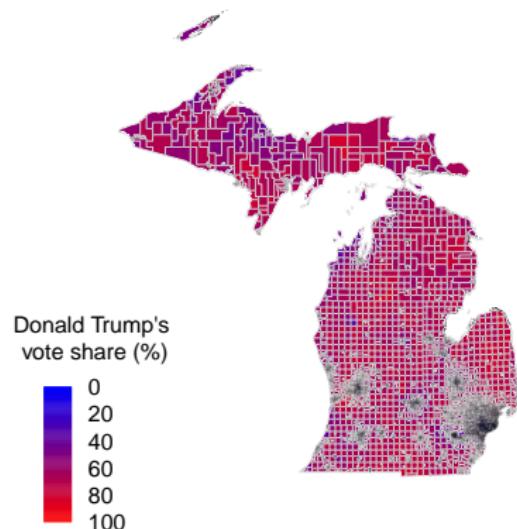
**Michigan 2020 Presidential Election Results**



Add a gradient legend, with the `SpectrumLegend` command from `PlotTools`

```
PlotTools::SpectrumLegend(  
  x = "bottomleft", title = "Donald Trump's\n vote share (%)",  
  palette = rgb(red=(100:0)/100,green=0,blue=(0:100)/100),  
  legend = seq(0,100,by=20), lwd = 10  
)
```

Michigan 2020 Presidential Election Results



Creating a **new variable** in R is quite simple

```
mi_2020$VOTEMARGIN = 100*(mi_2020$G20PRERTRU-mi_2020$G20PREDBID)/  
                           (mi_2020$G20PRERTRU+mi_2020$G20PREDBID)
```

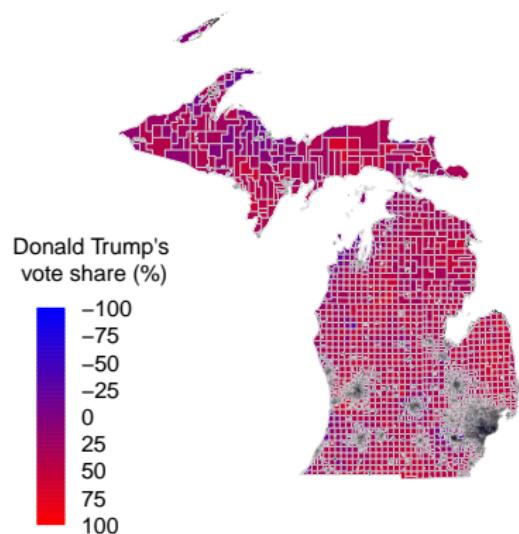
where

- mi\_2020 is the dataset, and \$ calls variables within it
- to the left of the = sign is the new variable you want to create
- to the right of = is an expression, specifying the calculation you want to make:  
$$\text{Vote Margin} = 100 \cdot \frac{\text{Trump} - \text{Biden}}{\text{Trump} + \text{Biden}}$$

To plot VOTEMARGIN, we can follow the same procedure as before, just modifying the color breaks and legend to reflect the new range of this variable

```
breaks = seq(-100,100,by=1)
...
PlotTools::SpectrumLegend(..., legend = seq(-100,100,by=25), ...)
```

Michigan 2020 Presidential Election Results



To **export your map as an image file**, use the `png()` command  
(or `pdf()`, `jpeg()`, `tiff()` for other file formats)

```
png(filename="Output/mi_2020_votemargin_r.png",width=6,height=6,units="in",res=150)
par(mar=c(0,0,0,0))
plot(mi_2020["VOTEMARGIN"],col=cols,lwd=.1,border=rgb(0,0,0,.1),
     main="Michigan 2020 Presidential Election Results")
PlotTools:::SpectrumLegend(x = "bottomleft",title = "Donald Trump's\n vote margin (%)",
    palette = rgb(red=(100:0)/100,green=0,blue=(0:100)/100),
    legend = seq(-100,100,by=20), lwd = 20, bty = "n")
dev.off()
```

where

- the `filename` argument specifies the location (e.g. `Output/`) and name (e.g. `mi_2020_votemargin_r.png`), in one string
- the `width` and `height` arguments specify the dimensions of the file
- `units` specifies the units of measurement (`in` = inches) and `res` specifies the resolution (150 pixels per inch)
- `dev.off()` closes the graphics device  
(everything between `png()` and `dev.off()` is printed to file)

The exported image should look like this: →

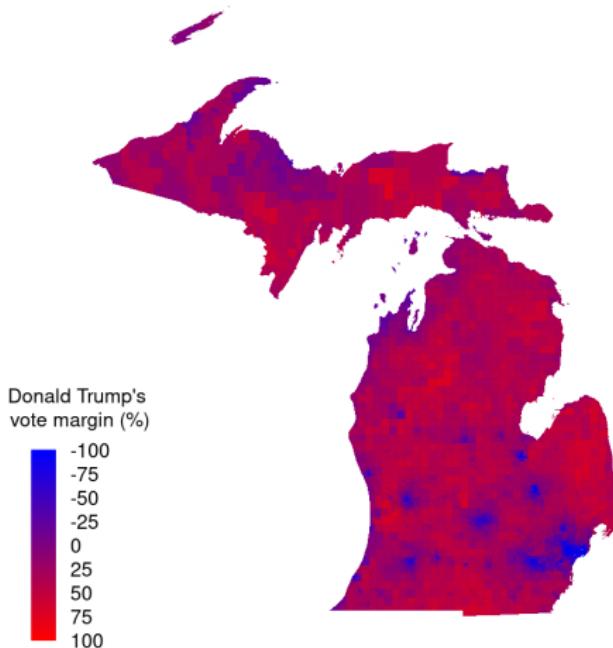


Figure 4: mi\_2020\_votemargin\_r.png

## Problem Set

## Massachusetts 2020 Presidential Election Results

**Your assignment** (if using R):

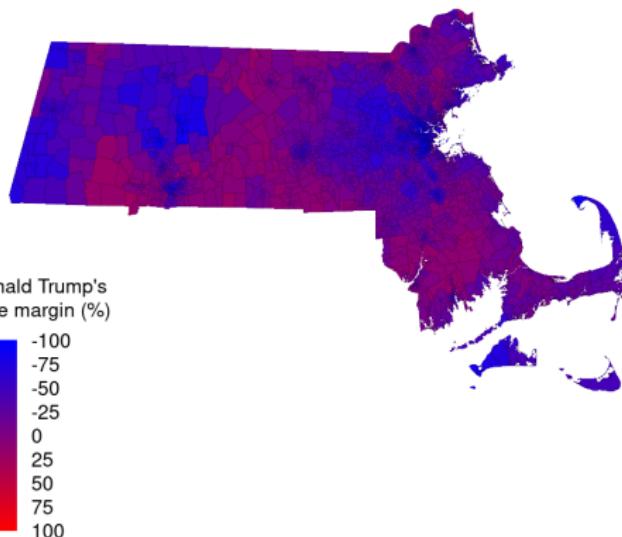
create the same kind of map for

Massachusetts, using dataset

`ma_2020.geojson`

(or any other state of your choice)

- precincts colored by  
`VOTEMARGIN` (new variable)
- name the file  
`ma_2020_votemargin_r.png`
- upload map to Canvas  
(by next Monday)

**Another option:**

do everything in Python!

(see `lab01_demo.py`)

Figure 5: Can you make this map?