Lesson 3:
Thematic and Analytical Mapping: tmap Methods

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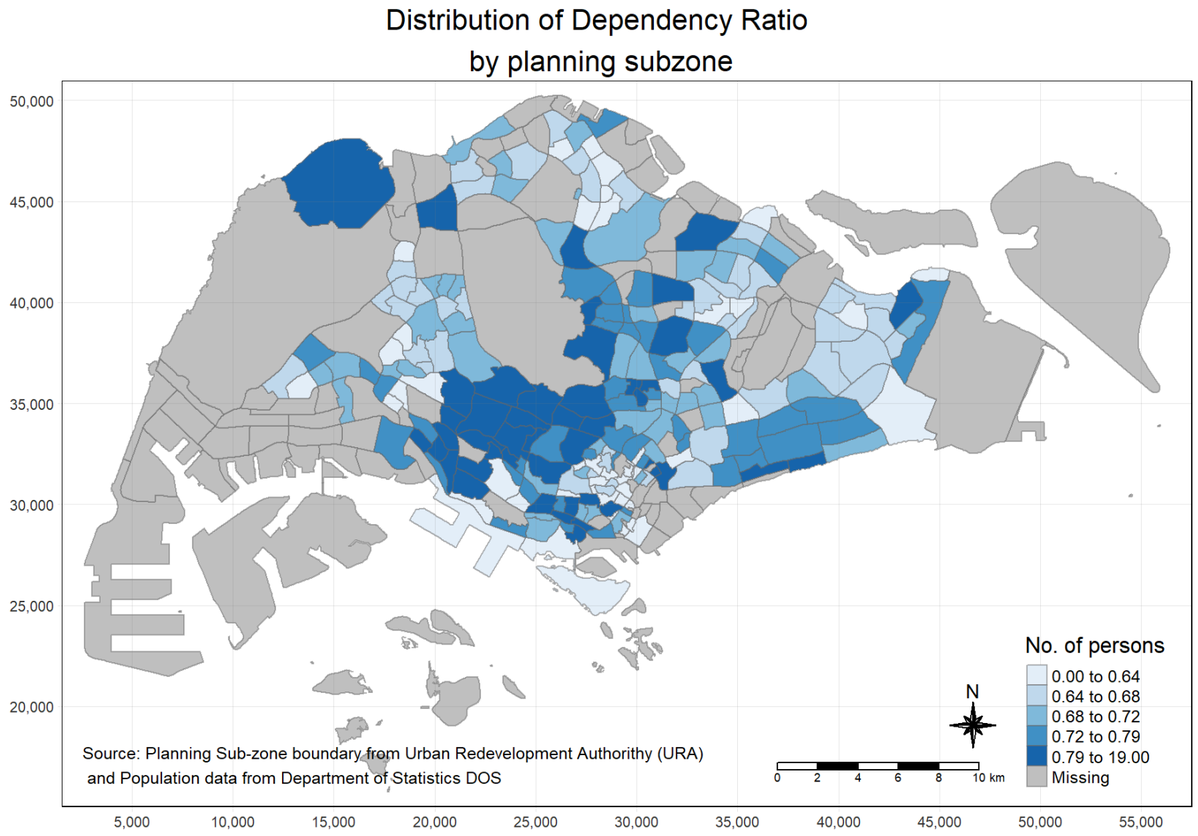
Choropleth Map

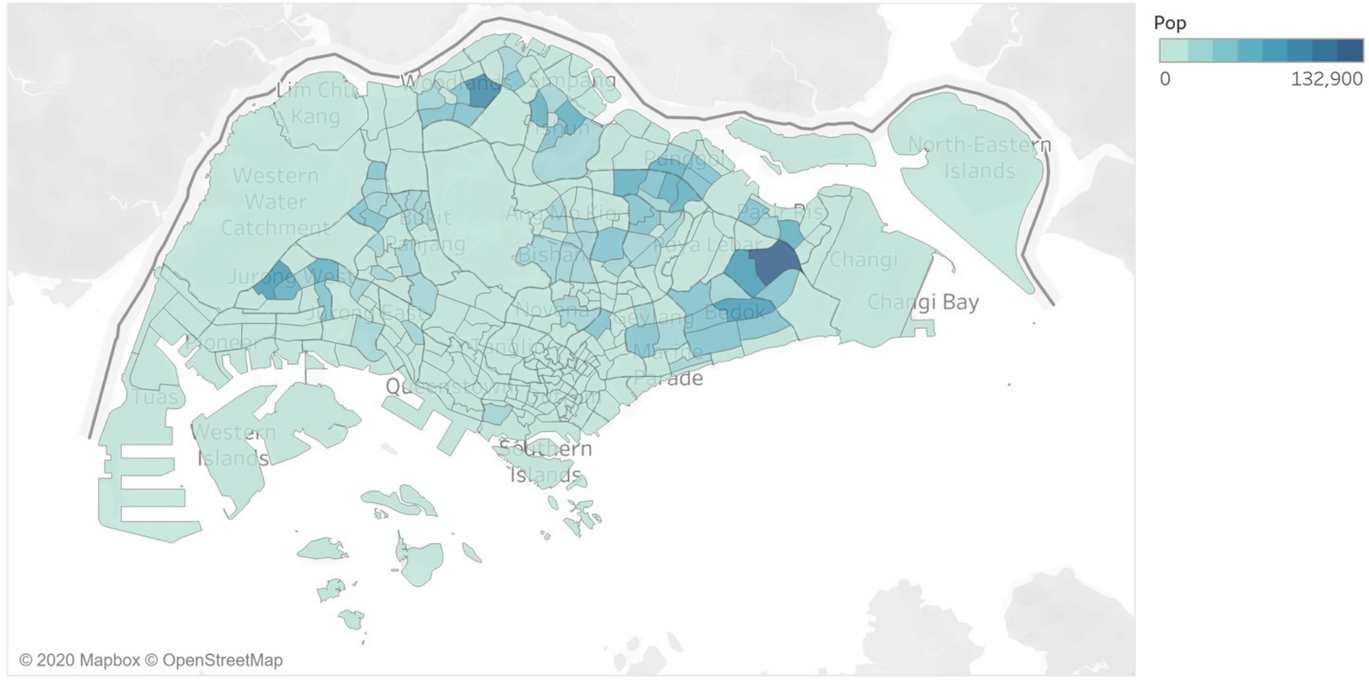
A choropleth map is a type of thematic map in which areas are shaded or patterned in proportion to a statistical variable that represents an aggregate summary of a geographic characteristic within each area, such as population or per-capita income.



Classified choropleth map

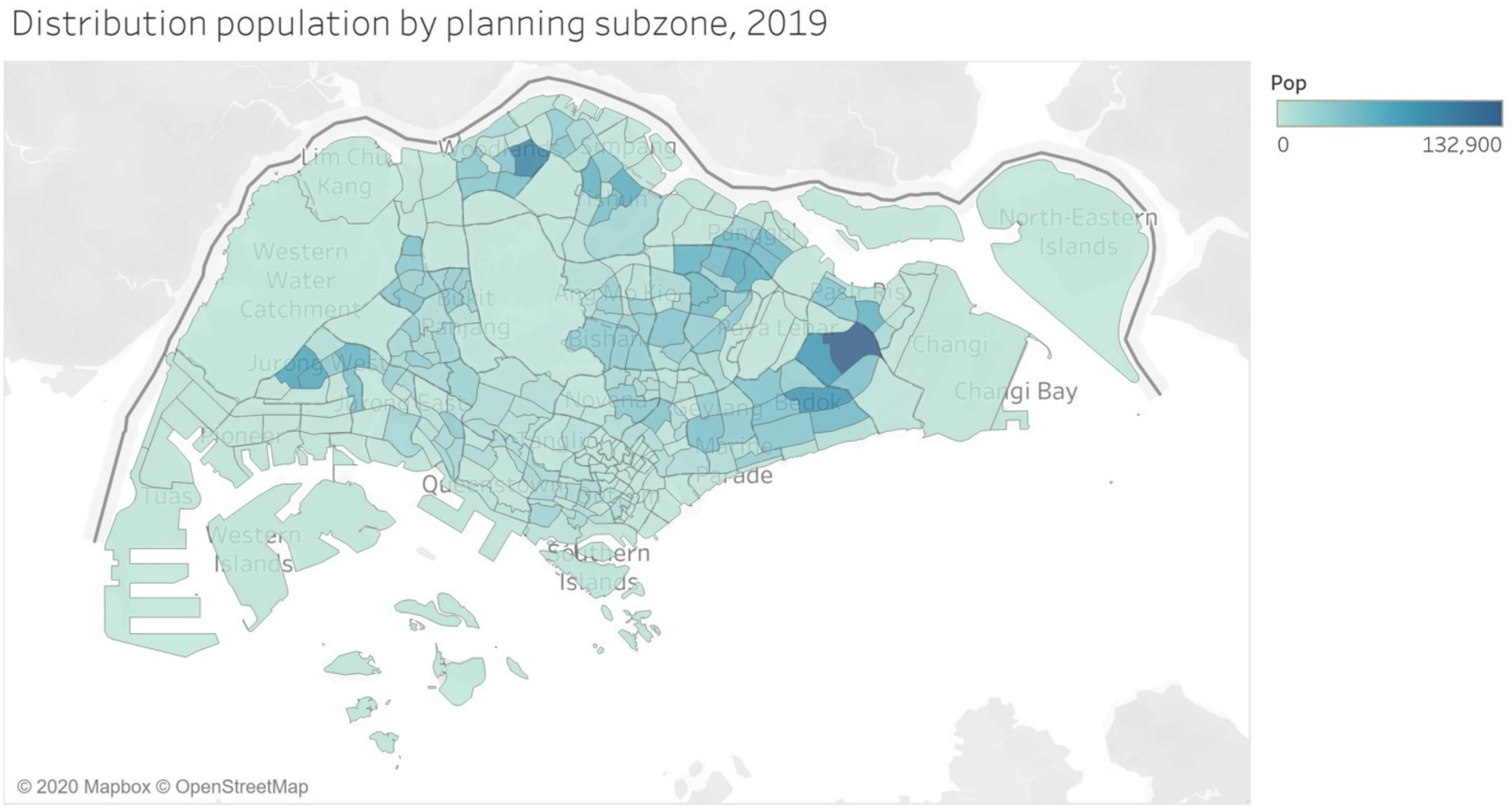
- Choropleth maps can be either classified or unclassified.
- A classed choropleth map combines areal units into a smaller number of groups. Interval levels may vary, but typically 4 to 7 are used in a map. There is different classification techniques used to divide up the intervals.

Distribution population by planning subzone, 2019



Unclassified choropleth map

- Unclassed choropleth maps are similar to classed choropleth maps; however, unclassed choropleth maps do not have an averaged statistic towards each particular colour.



Choosing an appropriate number of classes

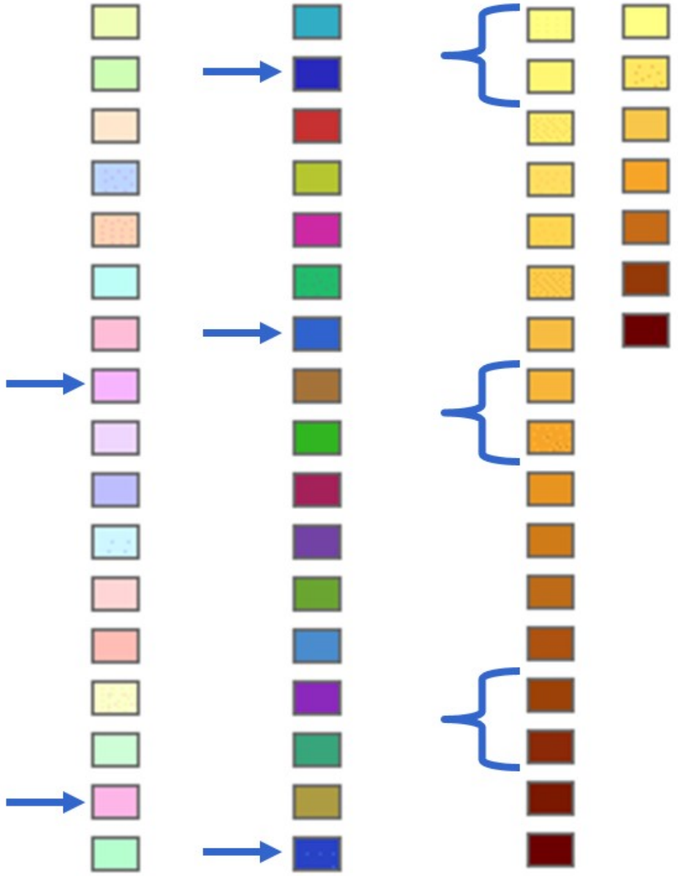
- Sturges' formula

$$k = 1 + 3.32 * \log n$$

n = number of values
k = number of classes

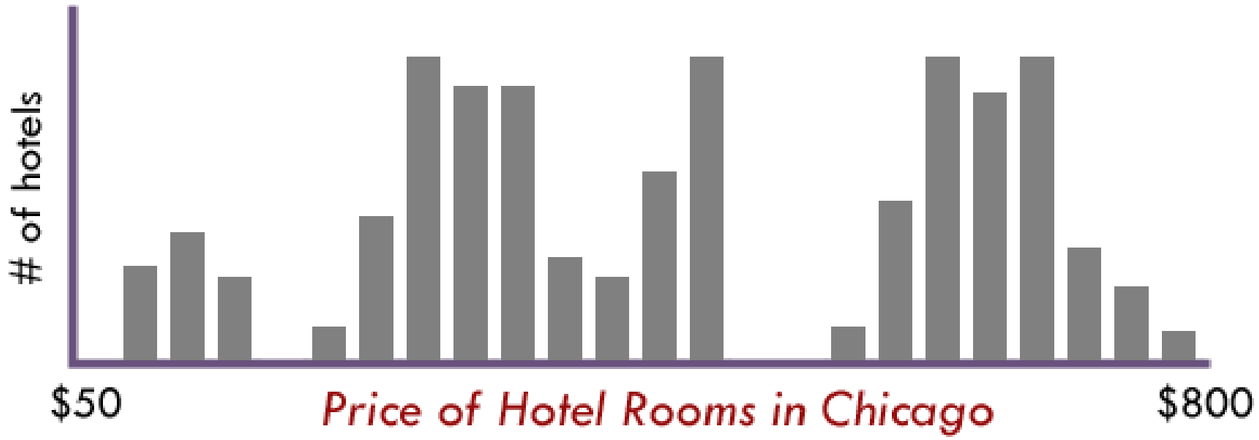
If n = 36
k = 1 + 3.32 * log n
k = 6 approx.

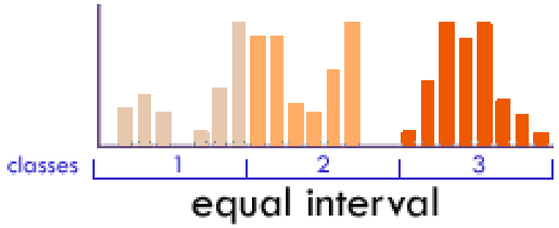
Example

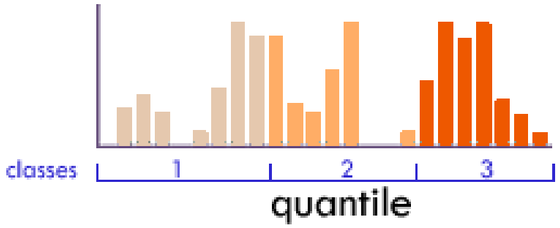


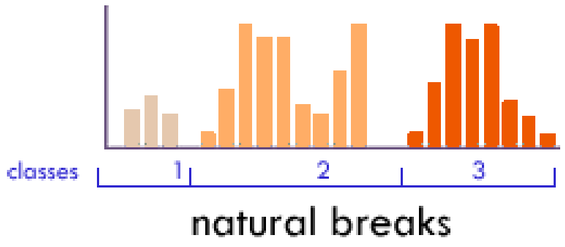
- Number of intervals?
  - Not less than 4
    - To avoid an overly generalized map
  - Not more than
    - 12 colors
    - 7 or 8 shades of the same color

Data classification







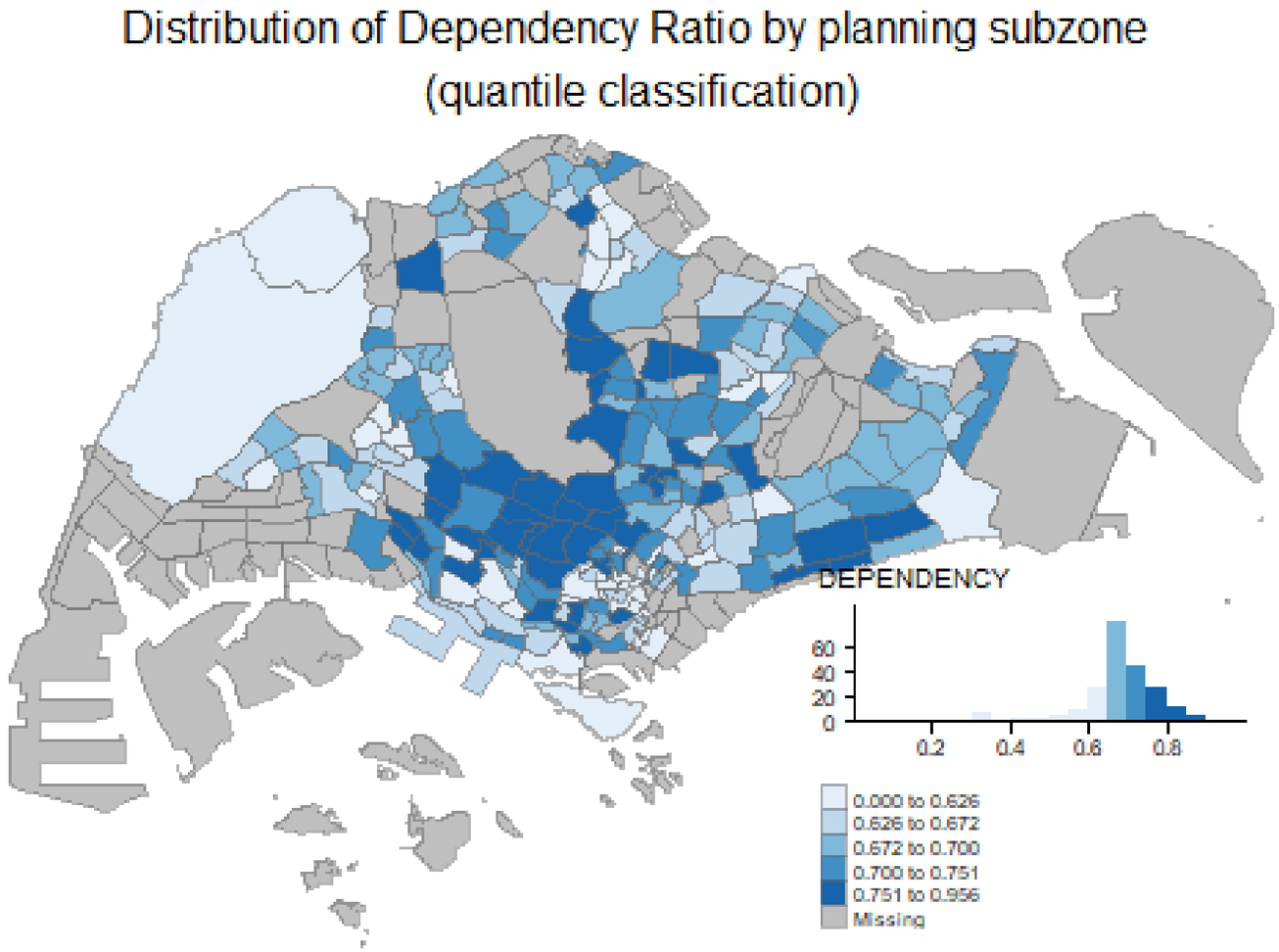


Methods of choosing classes

- Based on the nature of the distribution
  - quantile, equal interval, natural breaks, standard deviations, defined interval
- Arbitrary
  - Can be based on round numbers.
  - Examples: Grouping according to age or census housing categories
  - Can result in empty categories

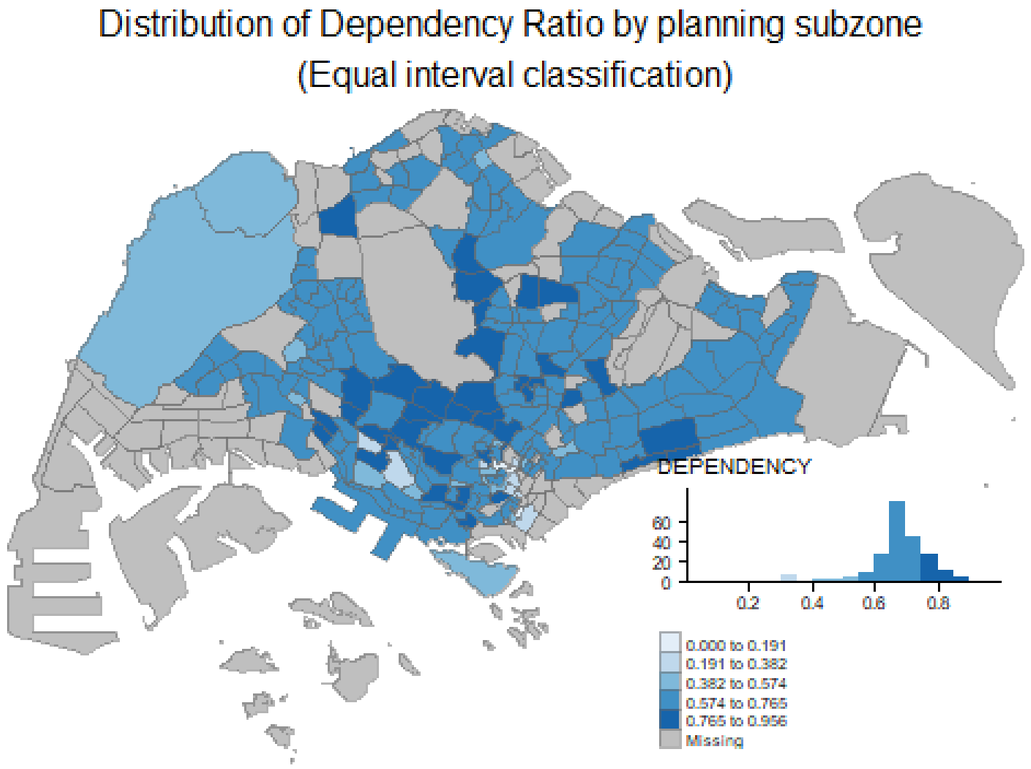
Data classification method: Quantile

- Same number of features per class.



Data classification method: Equal interval

- Divides the range of attribute values into equally sized classes.

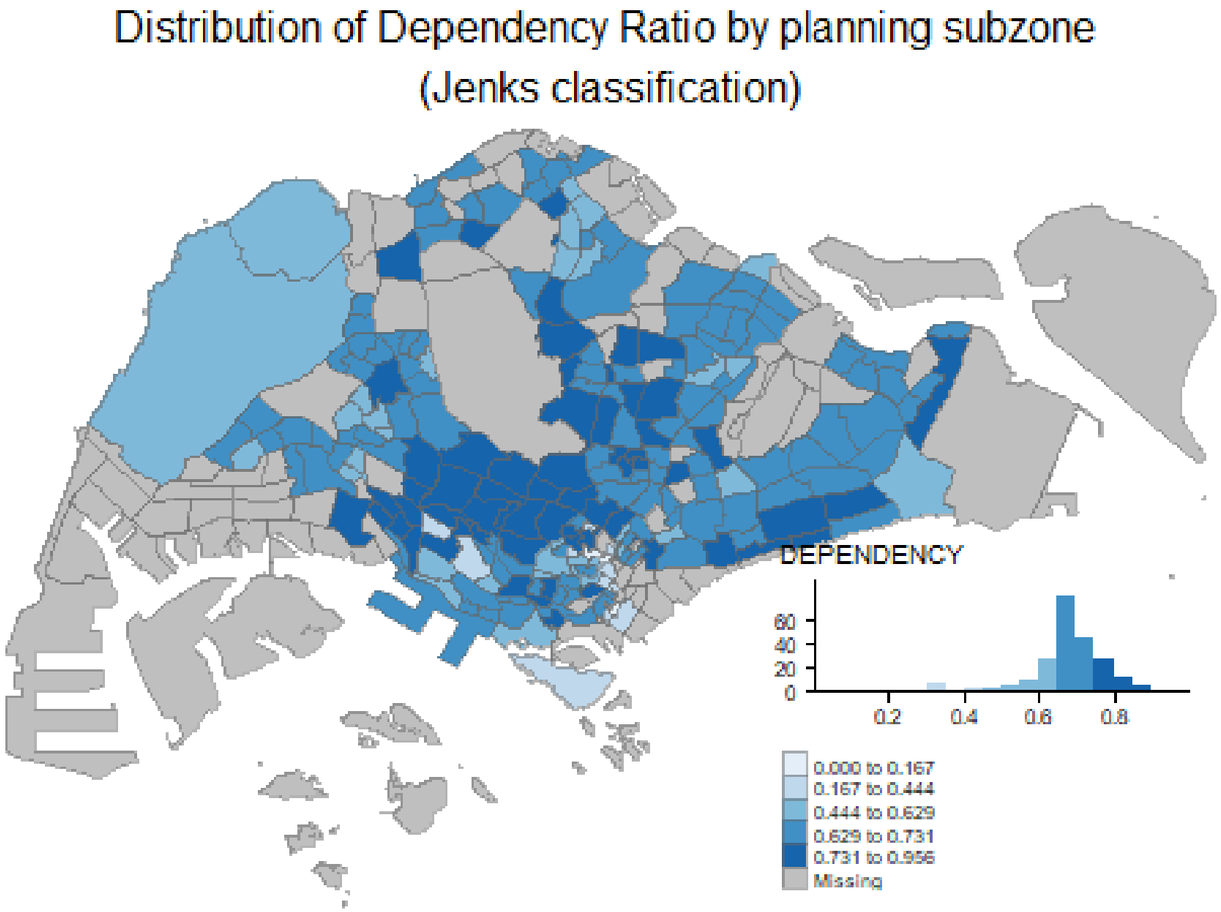


Caution

Avoid equal interval if your data are skewed to one end or if you have one or two really large outlier values. Outliers in that case will likely produce empty classes, wasting perfectly good classes with no observations in them. Since the hotel data above doesn't have really large outliers, this is a data distribution that works well with equal interval.

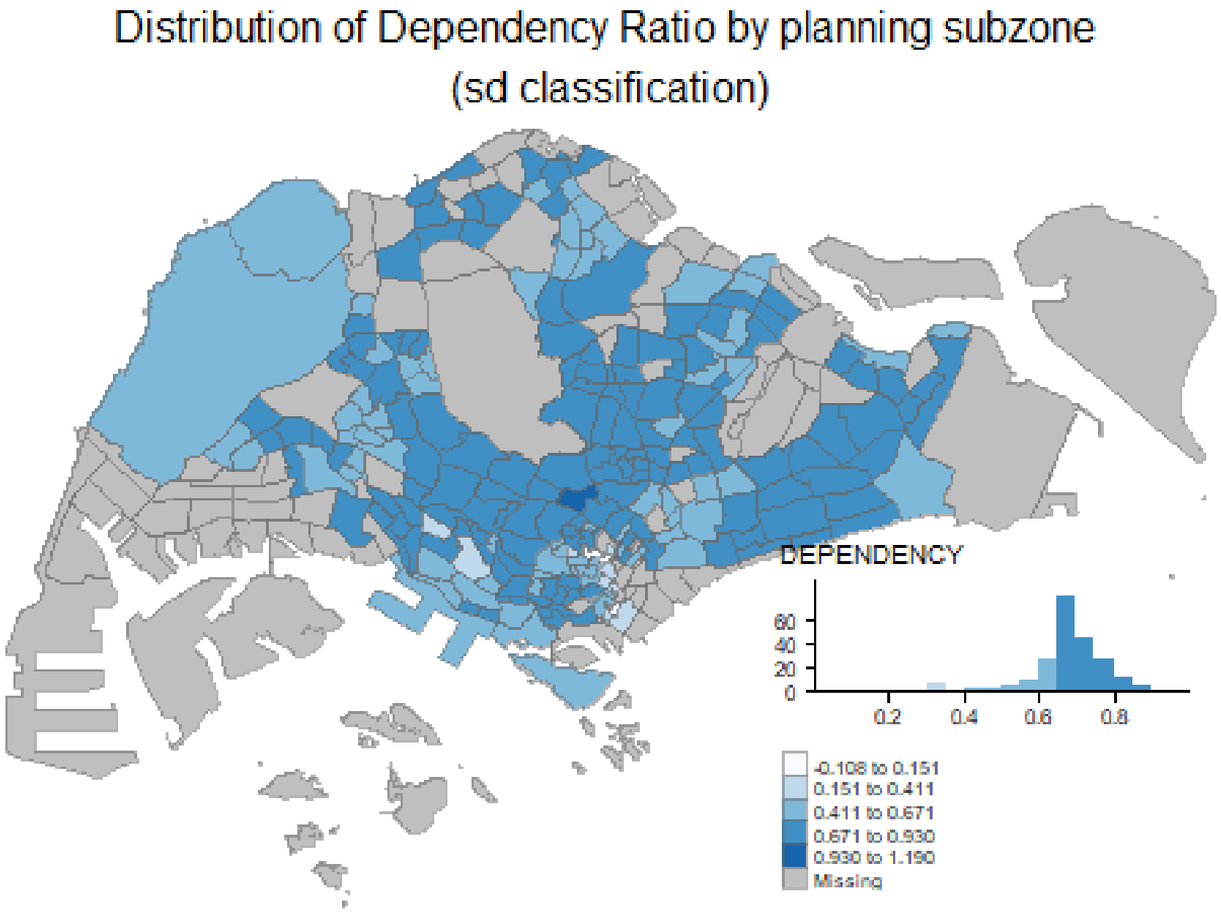
Data classification method: Jenks (also known as Natural breaks)

- Default Jenk's statistical optimization
- Finds natural groupings in the data



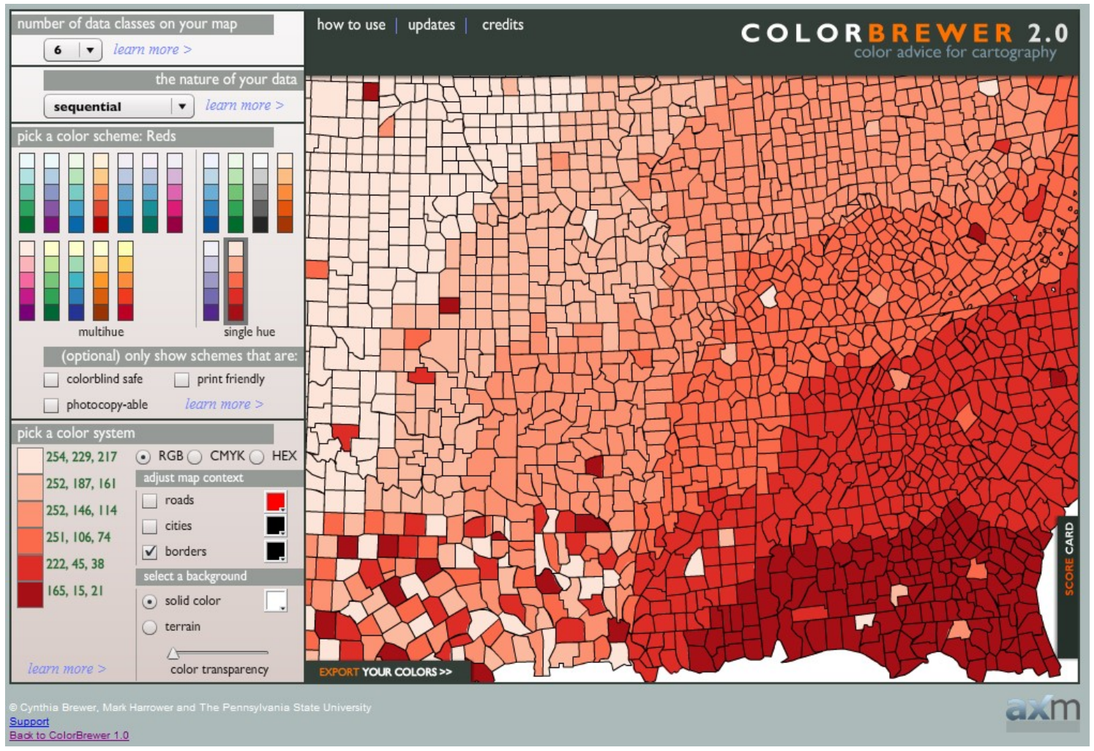
Data classification: Standard deviation

- A measure of dispersion.
- Use if the distribution approximates a normal distribution (bell-shaped curve)



Colour scheme

ColorBrewer



different hues that keep lightness and saturation constant should be used for **nominal data** (i.e., un-orderable categories, not numerical data).

any sequence that is **dominated by changes in lightness** can be used with orderable (rankable) categories (low/med/high) or with numerical data.

any numerical data **that can be divided meaningful at a mid-point** (e.g., national average, zero) can use a diverging scheme: the data are split in two around the lightest, middle color/class.

Mapping packages in R

Selected popular mapping packages

CRAN Task View: Analysis of Spatial Data

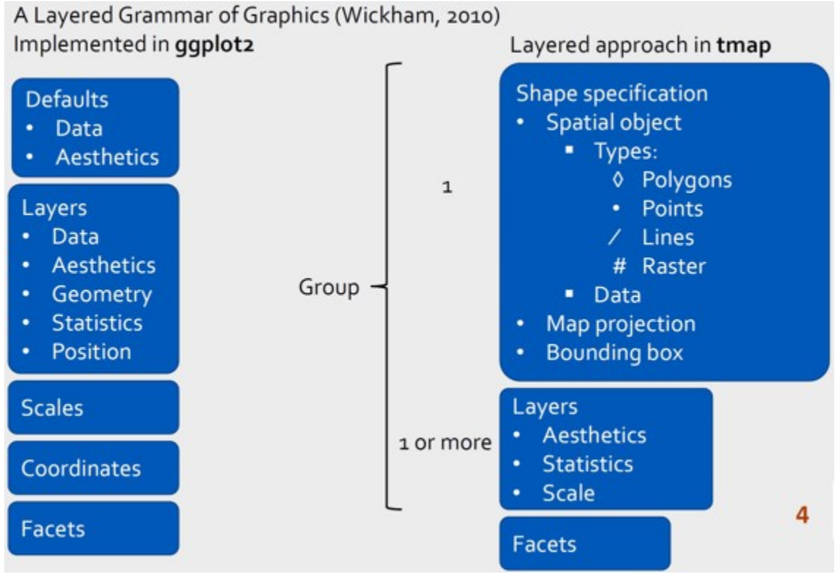
- tmap
- mapsf
- leaflet
- ggplot2. Read Chapter 6: Maps of ‘ggplot2: Elegant Graphics for Data Analysis’ for more detail.
- ggmap
- quickmapr
- mapview

Other packages

- RColorBrewer
- classInt

Introducing tmap

- **tmap** is a R package specially designed for creating thematic maps using the pricinples of the **Grammar of Graphics**.
- It offers a flexible, layer-based, and easy to use approach to create thematic maps, such as choropleths and proportional symbol maps.
- It supports two modes: *plot*(static maps) and *view* (interactive maps).
- It provides shiny integration(with *tmapOutput* and *renderTmap*).



Shape objects

- *tmap* supports **simple features** from the new *sf* package.
- It also supports the class Spatial and Raster, respectively from the *sp* and the *raster* package. The supported subclasses are:

	Without data	With data
Polygons	SpatialPolygons	SpatialPolygonsDataFrame
Points	SpatialPoints	SpatialPointsDataFrame
Lines	SpatialLines	SpatialLinesDataFrame
Raster	SpatialGrid	SpatialGridDataFrame
Raster	SpatialPixels	SpatialPixelsDataFrame
Raster		RasterLayer
Raster		RasterBrick
Raster		RasterStack

Plotting functions of tmap

Two approaches can be used to prepare thematic map using **tmap**, they are:

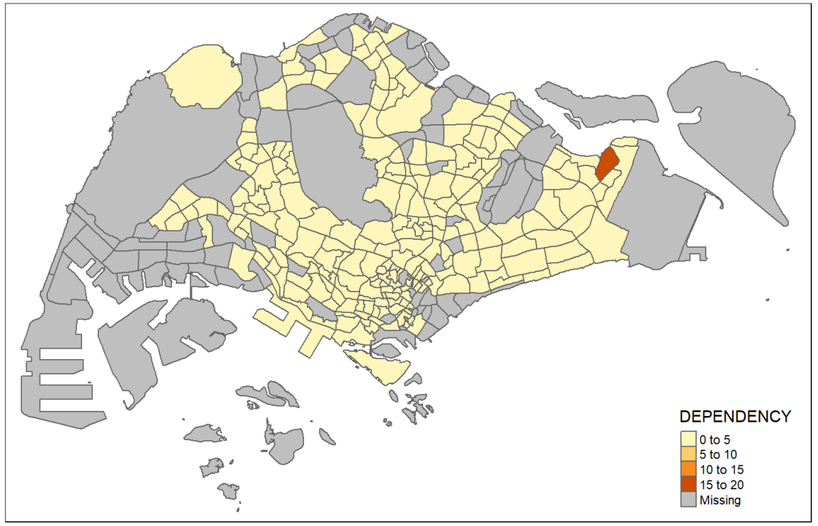
- Plotting a thematic map quickly by using `qtm()`.
- Plotting highly customisable thematic map by using tmap elements.

Plotting a choropleth map quickly by using `qtm()`

The easiest and quickest to draw a choropleth map using **tmap** is using `qtm()`. It is concise and provides a good default visualisation in many cases.

- `tmap_mode()` with “plot” option is used to produce a static map. For interactive mode, “view” option should be used.
- `fill` argument is used to map the attribute (i.e. DEPENDENCY)

```
tmap_mode("plot")
qtm(mpszpop2020,
    fill = "DEPENDENCY")
```



tmap elements

`tm_shape()`

- The first element to start with is `tm_shape()`, which specifies the shape object.

Function	Argument	Description	Spatial types
`tm_shape`	`shp`	shape object	polygons points lines raster cells
	`projection`	projection code	
	`bbox`	bounding box	

tmap elements

Base layers

- Next, one, or a combination of the following drawing layers should be specified:

Drawing layer	Description	Aesthetics
Base layer		
`tm_polygons`	Draw polygons	col
`tm_symbols`	Draws symbols	size, col, shape
`tm_lines`	Draws polylines	col, lwd
`tm_raster`	Draws a raster	col
`tm_text`	Add text labels	text, size, col

- Links to `tm_polygons()`, `tm_symbols()`, `tm_lines()`, `tm_raster()` and `tm_text()`

tmap elements

Base layers

- Each of these functions specifies the geometry, mapping, and scaling component of the LGTM.
- An aesthetic can take a constant value, a data variable name, or a vector consisting of values or variable names.
- If a data variable is provided, the scale is automatically configured according to the values of this variable, but can be adjusted with several arguments. For instance, the main scaling arguments for a color aesthetic are color palette, the preferred number of classes, and a style to create classes.
- Also, for each aesthetic, except for the text labels, a legend is automatically created.
- If a vector of variable names is provided, small multiples are created, which will be explained further below.

tmap elements

Derived layers

Each aesthetic can take a constant value or a data variable name. For instance, `tm_fill(col="blue")` colors all polygons blue, while `tm_fill(col="var1")`, where “var1” is the name of a data variable in the shape object, creates a choropleth.

The supported derived layers are as follows:

Derived layer		
`tm_fill`	Fills the polygons	see tm_polygons
`tm_borders`	Draws polygon borders	none
`tm_bubbles`	Draws bubbles	see tm_symbols
`tm_squares`	Draws squares	see tm_symbols
`tm_dots`	Draws dots	see tm_symbols
`tm_markers`	Draws markers	see tm_symbols and tm_text
`tm_iso`	Draws iso/contour lines	see tm_lines and tm_text

Drawing a base map

The basic building block of **tmap** is `tm_shape()` followed by one or more layer elements such as `tm_fill()` and `tm_polygons()`.

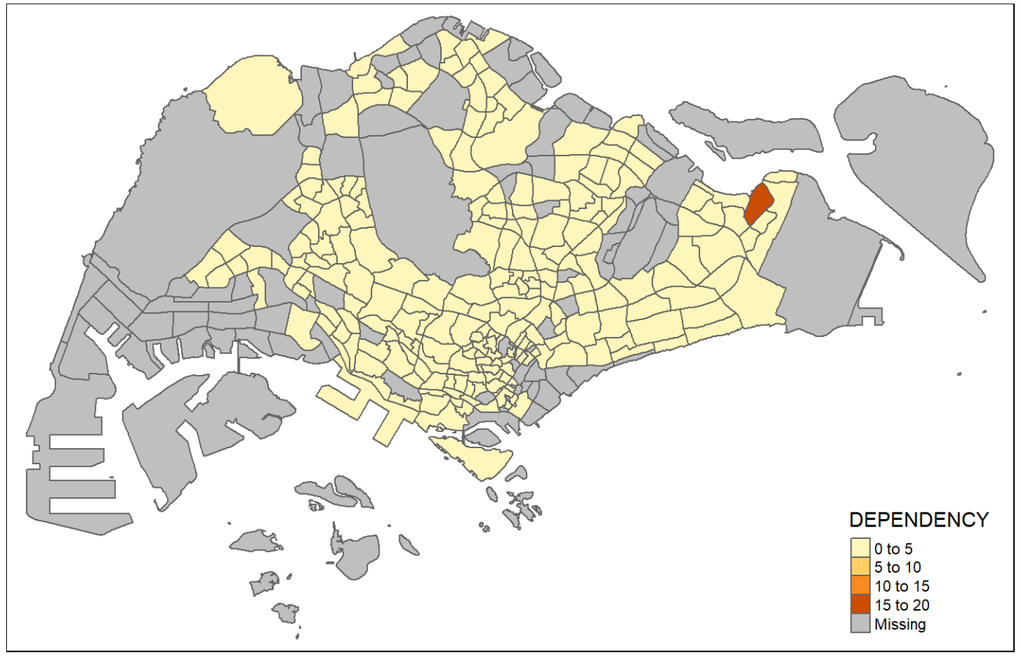
> ⚠ **Be warned**
>
> The “+” sign should be place at the end of a code line and not at the front of a code line.

```
1  tm_shape(mpszpop2020) +
2    tm_polygons()
```

Drawing a choropleth map using *tm_polygons()*

To draw a choropleth map showing the geographical distribution of a selected variable by planning subzone, we just need to assign the target variable such as *DEPENDENCY* to *tm_polygons()*.

```
tm_shape(mpszpop2020)+
  tm_polygons("DEPENDENCY")
```



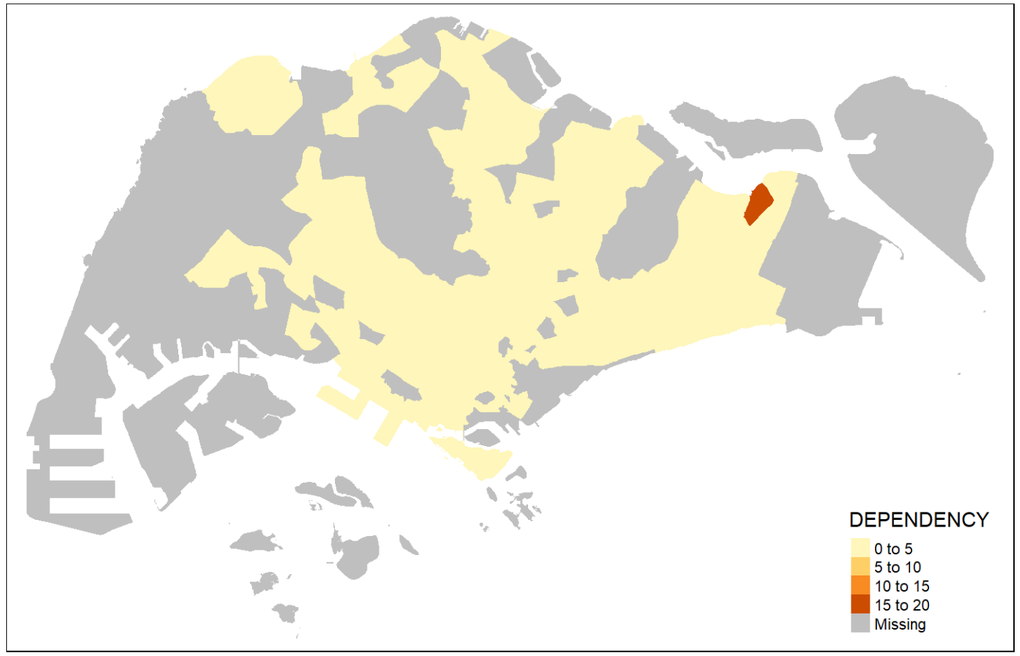
Things to learn from `tm_polygons()`:

- By default, 5 bins will be used.
- The default data classification method used is called “pretty”.
- The default colour scheme used is “YlOrRd” of ColorBrewer. You will learn more about the color palette later.
- By default, Missing value will be shaded in gray.

Drawing a choropleth map using `tm_fill()` and `tm_border()`

> **Note**
>
> - Actually, `tm_polygons()` is a wrapper of `tm_fill()` and `tm_border()`.
> - `tm_fill()` shades the polygons by using the default colour scheme.
> - `tm_borders()` adds the borders of the shapefile onto the choropleth map.
> - Notice that the planning subzones are shared according to the respective dependency values

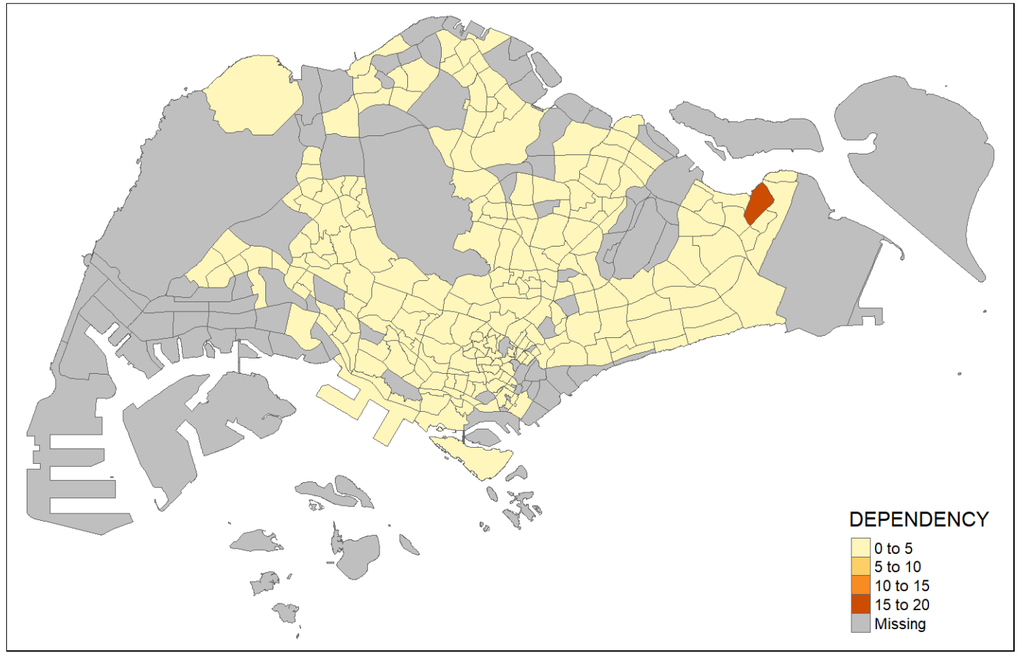
```
1 tm_shape(mpszpop2020) +
2   tm_fill("DEPENDENCY")
```



Drawing a choropleth map using `tm_border()`

To add the boundary of the planning subzones, `tm_border()` will be used.

```
tm_shape(mpszpop2020)+
  tm_fill("DEPENDENCY") +
  tm_borders(lwd = 0.1,
             alpha = 1)
```



Note

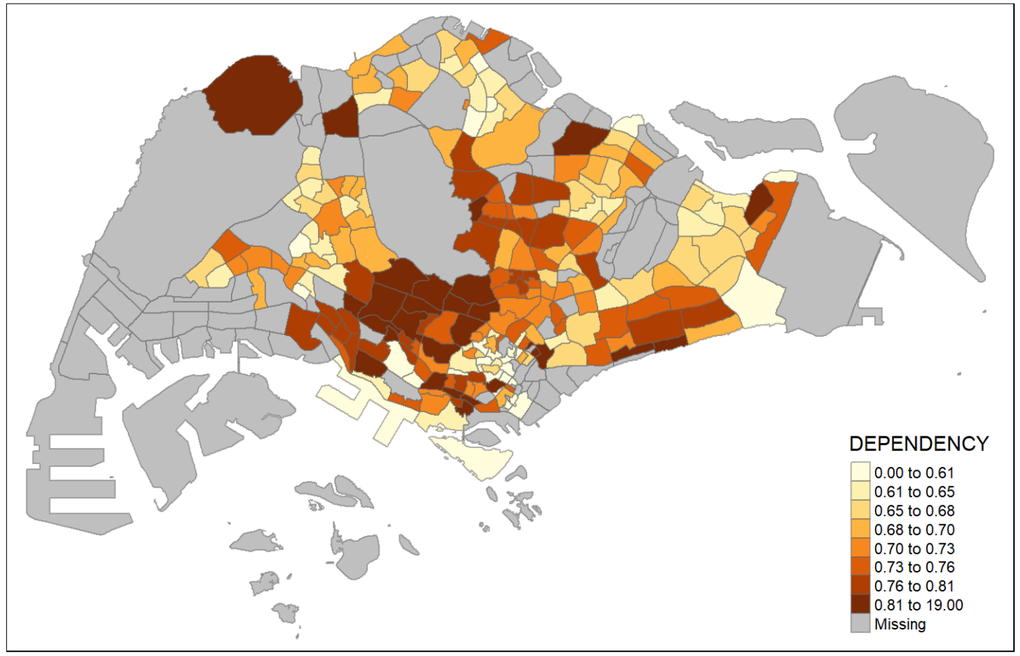
Notice that light-gray border lines have been added on the choropleth map.

- *lwd* = border line width. The default is 1,
- *alpha* = transparency number between 0 (totally transparent) and 1 (not transparent). By default, the alpha value of the col is used (normally 1),
- *col* = border colour, and
- *lty* = border line type. The default is “solid”.

Data classification methods of tmap

Most choropleth maps employ some method of data classification. The point of classification is to take a large number of observations and group them into data ranges or classes.

```
tm_shape(mpszpop2020)+
  tm_fill("DEPENDENCY",
          n = 8,
          style = "quantile") +
  tm_borders(alpha = 0.5)
```



Note

- **tmap** provides a total ten data classification methods, namely: *fixed*, *sd*, *equal*, *pretty* (default), *quantile*, *kmeans*, *hclust*, *bclust*, *fisher*, and *jenks*.
- To define a data classification method, the *style* argument of `tm_fill()` or `tm_polygons()` will be used.
- The choropleth map on the right shows a quantile data classification with 8 classes are used.

Comparing Quantile and Equal Interval

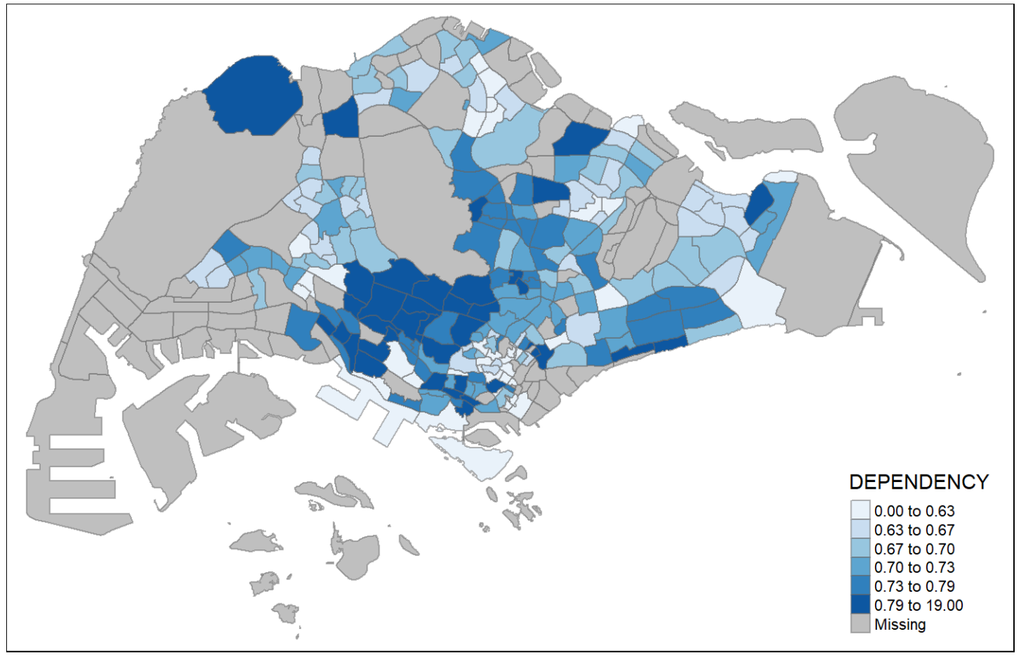
Choropleth maps on the left and right below show *quantile* and *equal* data classification methods are used.

Colour Scheme

tmap supports colour ramps either defined by the user or a set of predefined colour ramps from the **RColorBrewer** package.

> **Note**
>
> - To change the colour, we assign the preferred colour to *palette* argument of `tm_fill()`.
> - Notice that the word **blues** is used instead of blue and the alphabet b is in uppercase.

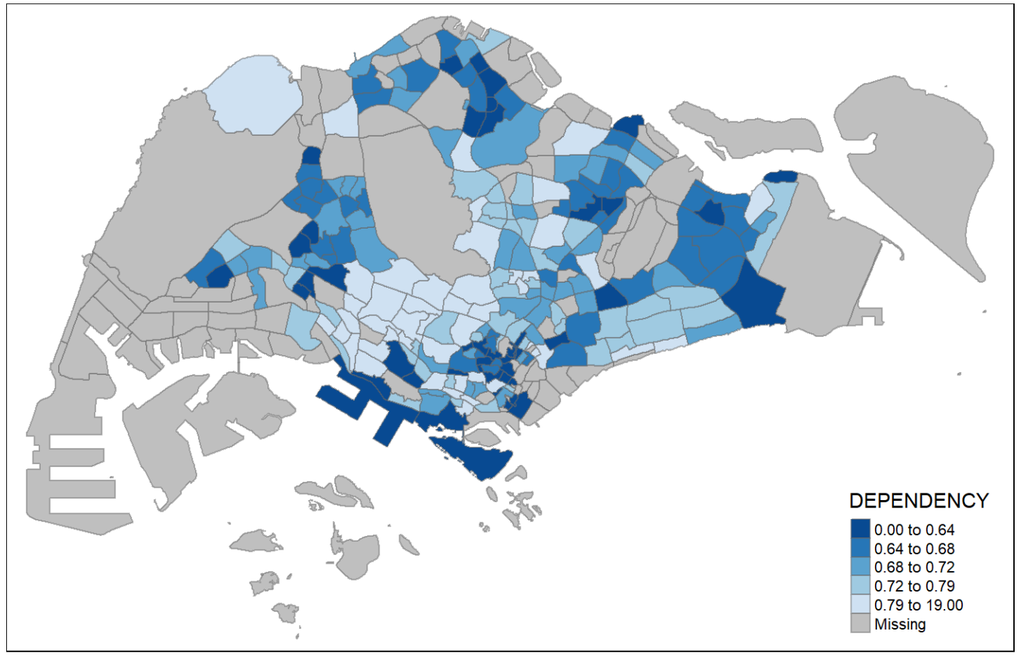
```
tm_shape(mpszpop2020)+
  tm_fill("DEPENDENCY",
          n = 6,
          style = "quantile",
          palette = "Blues") +
  tm_borders(alpha = 0.5)
```



More about colour

> **Note**
>
> - To reverse the colour shading, add a “-” prefix.

```
tm_shape(mpszpop2020)+
  tm_fill("DEPENDENCY",
          style = "quantile",
          palette = "-Blues") +
  tm_borders(alpha = 0.5)
```



Notice that the colour scheme has been reversed.

tmap Layouts

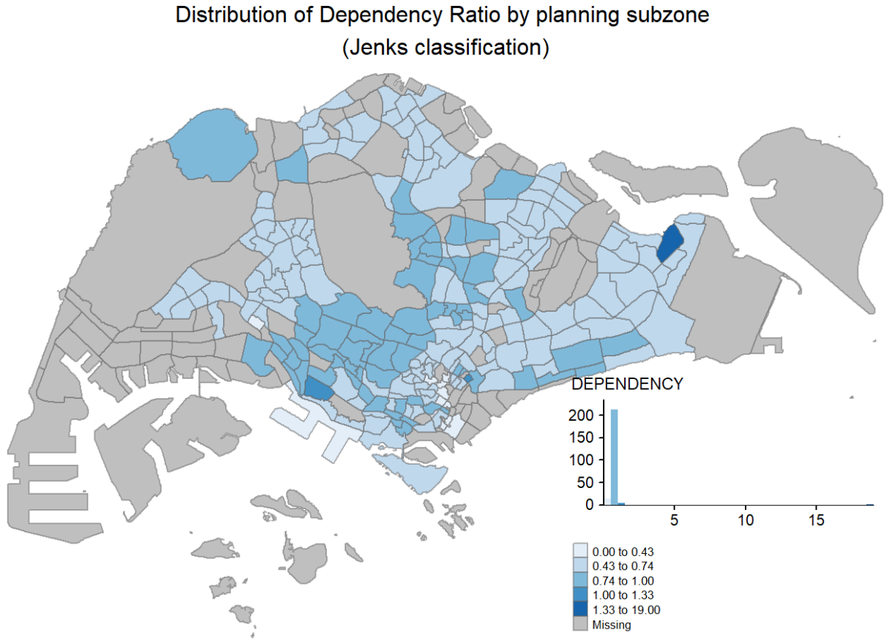
Map layout refers to the combination of all map elements into a cohensive map.

- **Map elements** include among others the objects to be mapped, the title, the scale bar, the compass, margins and aspects ratios, while the colour settings and data classification methods covered in the previous section relate to the palette and break-points used to affect how the map looks.

tmap Legend

In **tmap**, several *legend* options are provided to change the placement, format and appearance of the legend.

```
tm_shape(mpszpop2020)+
  tm_fill("DEPENDENCY",
          style = "jenks",
          palette = "Blues",
          legend.hist = TRUE,
          legend.is.portrait = TRUE,
          legend.hist.z = 0.1) +
  tm_layout(main.title = "Distribution of Dep
            main.title.position = "center",
            main.title.size = 1,
            legend.height = 0.45,
            legend.width = 0.35,
            legend.outside = FALSE,
            legend.position = c("right", "bot
            frame = FALSE) +
```



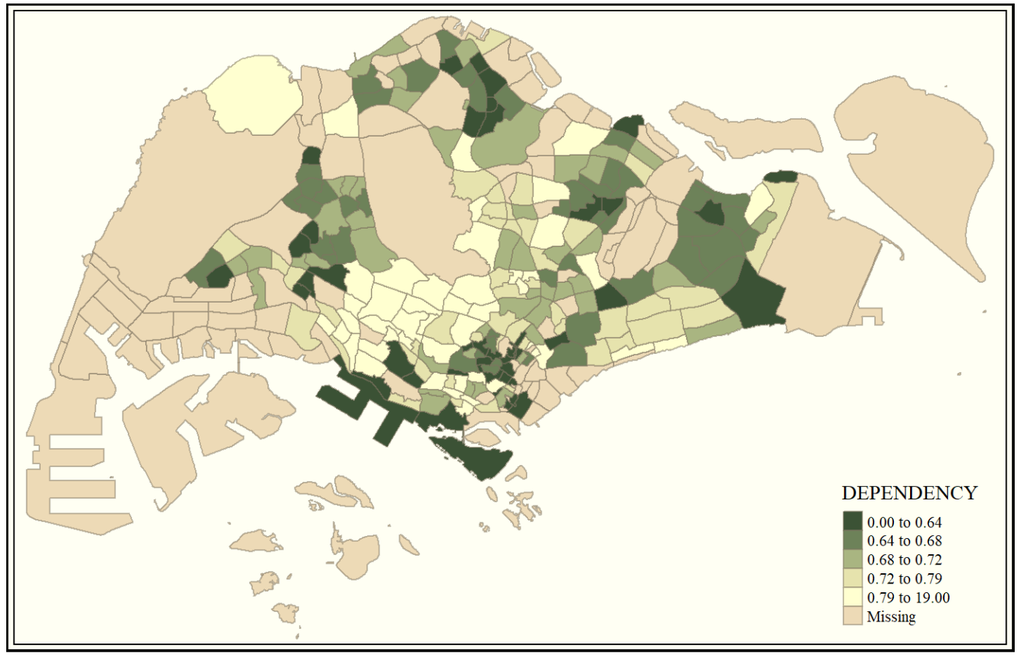
tmap style

tmap allows a wide variety of layout settings to be changed. They can be called by using `tmap_style()`.

> **Note**
>
> - “white”: White background, commonly used colors (default)
> - “gray”/“grey”: Grey background, useful to highlight sequential palettes (e.g. in choropleths)
> - “natural”: Emulation of natural view: blue waters and green land
> - “bw”: Greyscale, obviously useful for greyscale printing
> - “classic”: Classic styled maps (recommended)
> - “cobalt”: Inspired by latex beamer style cobalt
> - “albatross”: Inspired by latex beamer style albatross
> - “beaver”: Inspired by latex beamer style beaver

Chloropleth map below is plotted by using *classic* style.

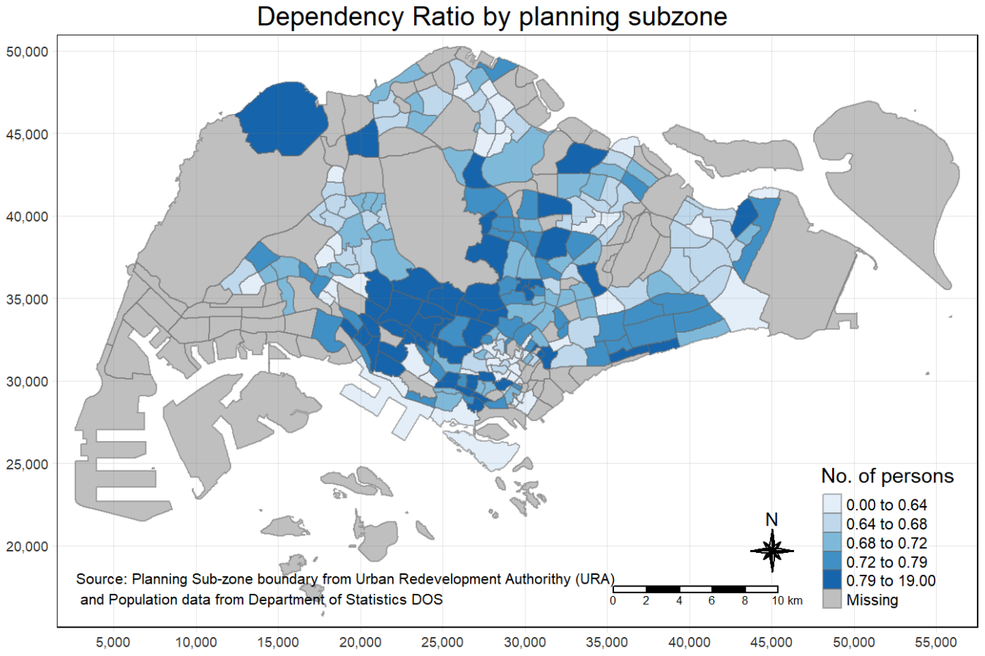
```
tm_shape(mpszpop2020)+
  tm_fill("DEPENDENCY",
          style = "quantile",
          palette = "-Greens") +
  tm_borders(alpha = 0.5) +
  tmap_style("classic")
```



Cartographic Furniture

Beside map style, **tmap** also also provides arguments to draw other map furniture such as compass, scale bar and grid lines. In the choropleth below, `tm_compass()`, `tm_scale_bar()` and `tm_grid()` are used to add compass, scale bar and grid lines onto the choropleth map.

```
tm_shape(mpszpop2020)+
  tm_fill("DEPENDENCY",
          style = "quantile",
          palette = "Blues",
          title = "No. of persons") +
  tm_layout(main.title = "Distribution of Dep
            main.title.position = "center",
            main.title.size = 1.2,
            legend.height = 0.45,
            legend.width = 0.35,
            frame = TRUE) +
  tm_borders(alpha = 0.5) +
  tm_compass(type="8star", size = 2) +
  tm_scale_bar(width = 0.15) +
  tm_grid(lwd = 0.1, alpha = 0.2) +
```



Drawing Small Multiple Choropleth Maps

Small multiple maps, also refered to facet maps, are composed of many maps arrange side-by-side, and sometimes stacked vertically. Small multiple maps enable the visualisation of how spatial relationships change with respect to another variable, such as time.

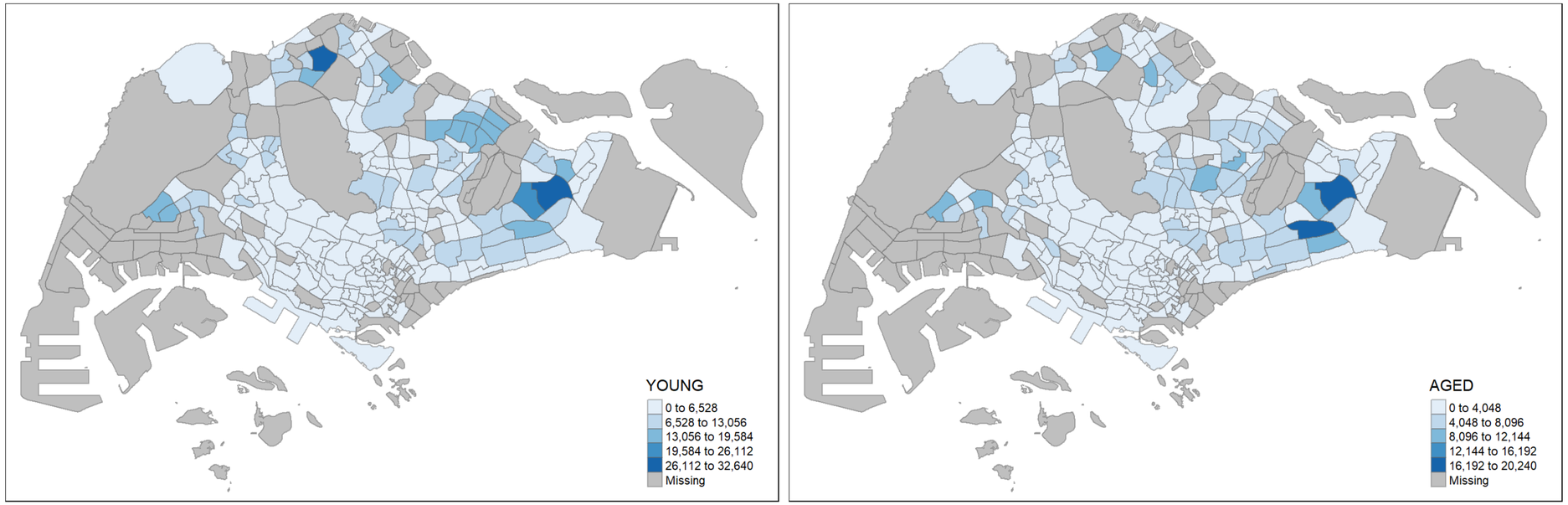
In **tmap**, small multiple maps can be plotted in three ways:

- by assigning multiple values to at least one of the asthetic arguments,
- by defining a group-by variable in *tm_facets()*, and
- by creating multiple stand-alone maps with *tmap_arrange()*.

By assigning multiple values to at least one of the aesthetic arguments

In this example, small multiple choropleth maps are created by defining *ncols* in `tm_fill()`.

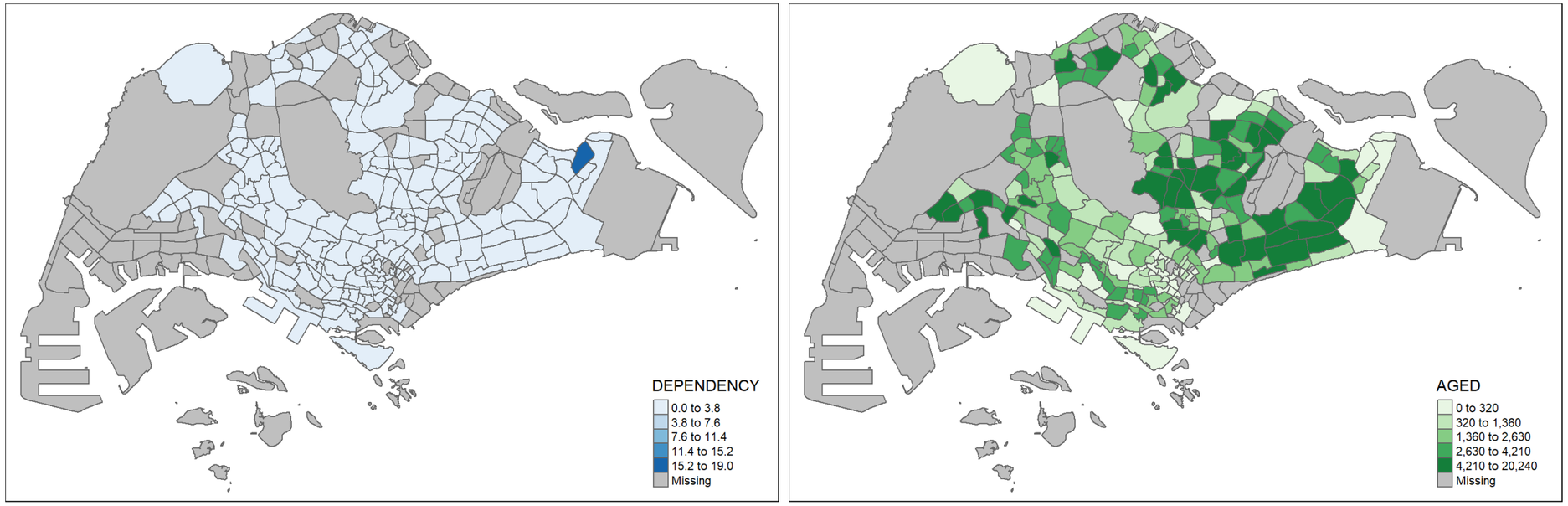
```
tm_shape(mpszpop2020)+
  tm_fill(c("YOUNG", "AGED"),
          style = "equal",
          palette = "Blues") +
  tm_layout(legend.position = c("right", "bottom")) +
  tm_borders(alpha = 0.5) +
  tmap_style("white")
```



By assigning multiple values to at least one of the aesthetic arguments

In this example, small multiple choropleth maps are created by assigning multiple values to at least one of the aesthetic arguments

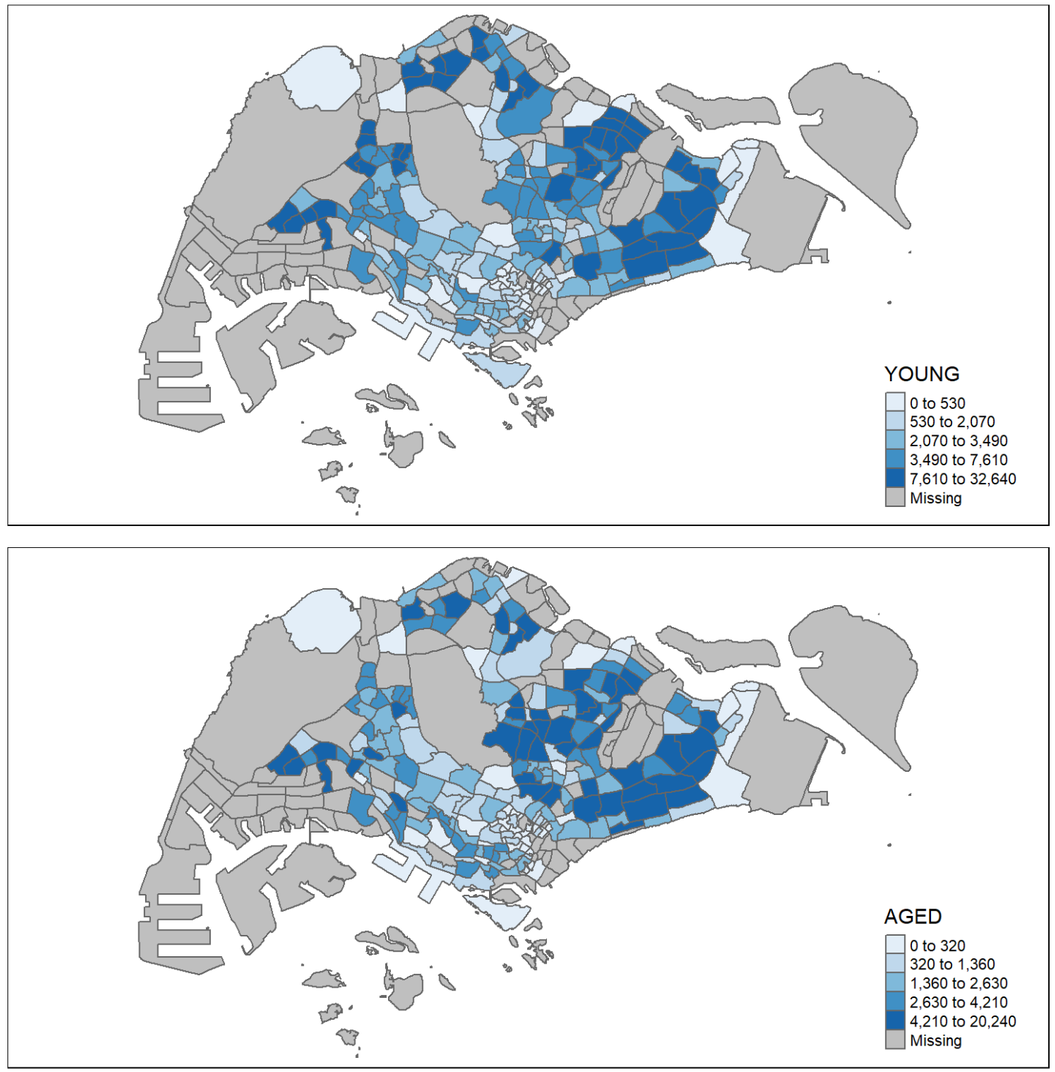
```
tm_shape(mpszpop2020)+
  tm_polygons(c("DEPENDENCY","AGED"),
          style = c("equal", "quantile"),
          palette = list("Blues","Greens")) +
  tm_layout(legend.position = c("right", "bottom"))
```



By creating multiple stand-alone maps with `tmap_arrange()`

In this example, multiple small choropleth maps are created by creating multiple stand-alone maps with `tmap_arrange()`.

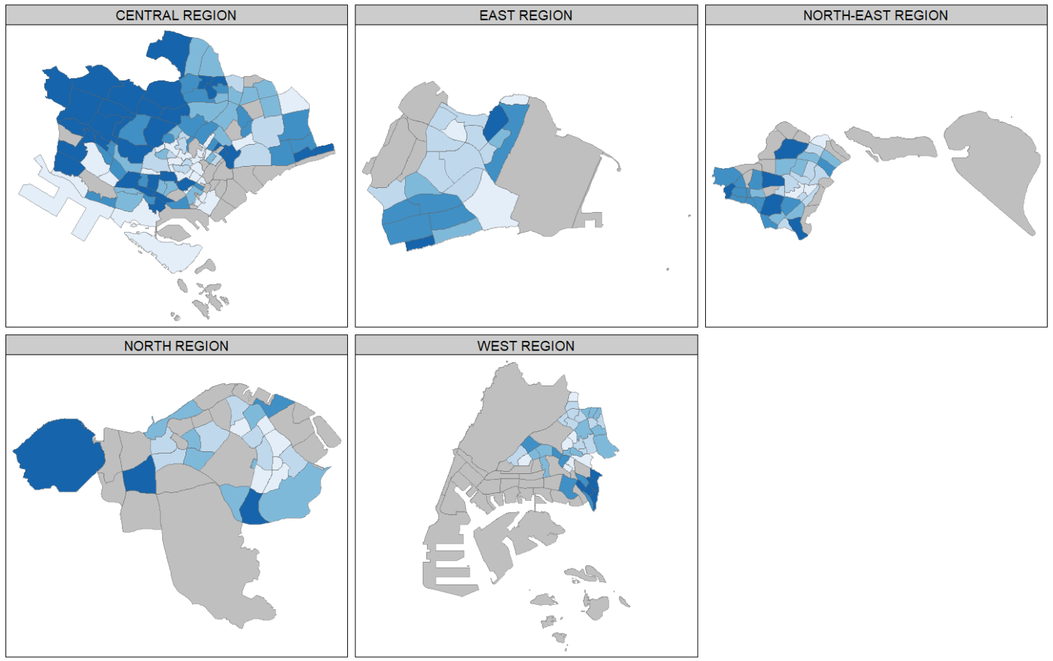
```
youngmap <- tm_shape(mpszpop2020)+
  tm_polygons("YOUNG",
              style = "quantile",
              palette = "Blues")

agedmap <- tm_shape(mpszpop2020)+
  tm_polygons("AGED",
              style = "quantile",
              palette = "Blues")

tmap_arrange(youngmap,
             agedmap,
             ncol=1)
```



By defining a group-by variable in `tm_facets()`

In this example, multiple small choropleth maps are created by using `tm_facets()`.

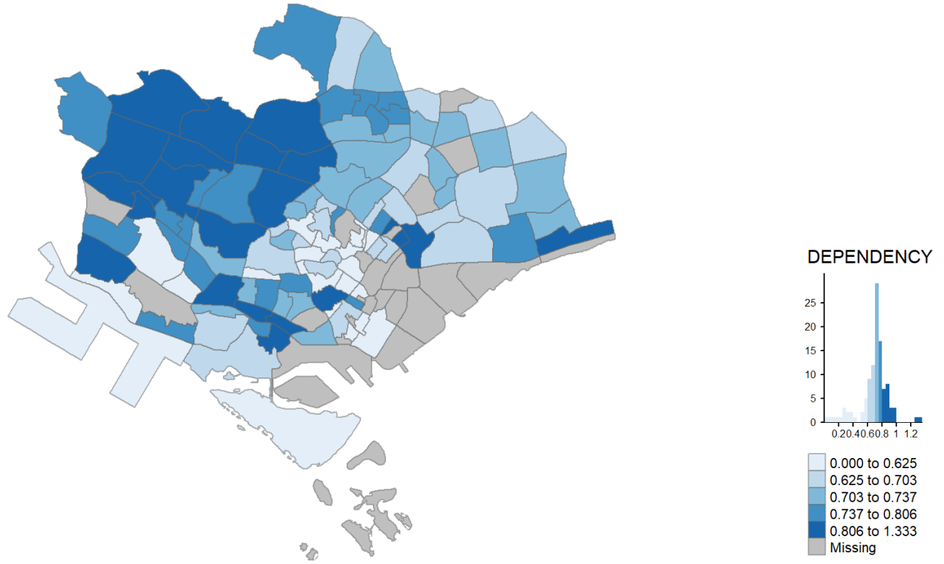
```
tm_shape(mpszpop2020) +
  tm_fill("DEPENDENCY",
          style = "quantile",
          palette = "Blues",
          thres.poly = 0) +
  tm_facets(by="REGION_N",
            free.coords=TRUE,
            drop.shapes=TRUE) +
  tm_layout(legend.show = FALSE,
            title.position = c("center",
                               "center"),
            title.size = 20) +
  tm_borders(alpha = 0.5)
```



Mappping Spatial Object Meeting a Selection Criterion

Instead of creating small multiple choropleth map, you can also use selection function to map spatial objects meeting the selection criterion.

```
tm_shape(mpszpop2020
         [mpszpop2020$REGION_N=="CENTRAL REGI
  tm_fill("DEPENDENCY",
          style = "quantile",
          palette = "Blues",
          legend.hist = TRUE,
          legend.is.portrait = TRUE,
          legend.hist.z = 0.1) +
  tm_layout(legend.outside = TRUE,
            legend.height = 0.45,
            legend.width = 5.0,
            legend.position = c("right",
                                "bottom"),
            frame = FALSE) +
  tm_borders(alpha = 0.5)
```



Reference

Principles, Concepts and Methods of Choropleth Maps Design

Core Reading

- Choropleth Maps
- The Basics of Data Classification

Additional Readings

- Choropleth Maps – A Guide to Data Classification
- Bivariate Choropleth
- Value-by-alpha maps
- What to consider when creating choropleth maps
- Choropleth Mapping with Exploratory Data Analysis

References

All About tmap package

- tmap: Thematic Maps in R
- Development site
- tmap Reference
- tmap: get started!
- tmap: version changes
- tmap: creating thematic maps in a flexible way (useR!2015)
- Exploring and presenting maps with tmap (useR!2017)