ISSS608

Choropleth Mapping with R

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Overview

Choropleth mapping involves the symbolisation of enumeration units, such as countries, provinces, states, counties or census units, using area patterns or graduated colors. For example, a social scientist may need to use a choropleth map to portray the spatial distribution of aged population of Singapore by Master Plan 2014 Subzone Boundary.

In this chapter, you will learn how to plot functional and truthful choropleth maps by using an R package called **tmap** package.

Survival Tip

It is advisable for you to read the functional description of each function before using them.

Getting Started

In this hands-on exercise, the key R package use is tmap package in R. Beside **tmap** package, four other R packages will be used. They are:

- readr for importing delimited text file,
- tidyr for tidying data,
- dplyr for wrangling data and
- sf for handling geospatial data.

Among the four packages, **readr**, **tidyr** and **dplyr** are part of **tidyverse** package.

The code chunk below will be used to install and load these packages in RStudio.

```
pacman::p_load(sf, tmap, tidyverse)
```

Notice that, we only need to install **tidyverse** instead of **readr**, **tidyr** and **dplyr** individually.

Importing Data into R

The Data

Two data set will be used to create the choropleth map. They are:

- Master Plan 2014 Subzone Boundary (Web) (i.e. `MP14_SUBZONE_WEB_PL`) in ESRI shapefile format. It can be downloaded at data.gov.sg This is a geospatial data. It consists of the geographical boundary of Singapore at the planning subzone level. The data is based on URA Master Plan 2014.

- Singapore Residents by Planning Area / Subzone, Age Group, Sex and Type of Dwelling, June 2011-2020 in csv format (i.e. `respopagesextod2011to2020.csv`). This is an aspatial data fie. It can be downloaded at Department of Statistics, Singapore Although it does not contain any coordinates values, but it's PA and SZ fields can be used as unique identifiers to geocode to `MP14_SUBZONE_WEB_PL` shapefile.

Importing Geospatial Data into R

The code chunk below uses the *st_read()* function of **sf** package to import `MP14_SUBZONE_WEB_PL` shapefile into R as a simple feature data frame called `mpsz`.

```
mpsz <- st_read(dsn = "data/geospatial", 
                layer = "MP14_SUBZONE_WEB_PL")
```

```
Reading layer `MP14_SUBZONE_WEB_PL' from data source 
  `D:\tskam\ISSS608-AY2022-23Jan\hands-on_ex\Hands-on_Ex07\data\geospatial' 
  using driver `ESRI Shapefile'
Simple feature collection with 323 features and 15 fields
Geometry type: MULTIPOLYGON
Dimension:     XY
Bounding box:  xmin: 2667.538 ymin: 15748.72 xmax: 56396.44 ymax: 50256.33
Projected CRS: SVY21
```

You can examine the content of `mpsz` by using the code chunk below.

```
mpsz
```

```
Simple feature collection with 323 features and 15 fields
Geometry type: MULTIPOLYGON
Dimension:     XY
Bounding box:  xmin: 2667.538 ymin: 15748.72 xmax: 56396.44 ymax: 50256.33
Projected CRS: SVY21
First 10 features:
   OBJECTID SUBZONE_NO       SUBZONE_N SUBZONE_C CA_IND      PLN_AREA_N
1         1          1    MARINA SOUTH    MSSZ01      Y    MARINA SOUTH
2         2          1    PEARL'S HILL    OTSZ01      Y          OUTRAM
3         3          3       BOAT QUAY    SRSZ03      Y SINGAPORE RIVER
4         4          8  HENDERSON HILL    BMSZ08      N     BUKIT MERAH
```

```
5         5           3         REDHILL    BMSZ03       N     BUKIT MERAH
6         6           7  ALEXANDRA HILL    BMSZ07       N     BUKIT MERAH
7         7           9   BUKIT HO SWEE    BMSZ09       N     BUKIT MERAH
8         8           2     CLARKE QUAY    SRSZ02       Y SINGAPORE RIVER
9         9          13 PASIR PANJANG 1    QTSZ13       N      QUEENSTOWN
10       10           7       QUEENSWAY    QTSZ07       N      QUEENSTOWN
   PLN_AREA_C       REGION_N REGION_C          INC_CRC FMEL_UPD_D   X_ADDR
1          MS CENTRAL REGION       CR 5ED7EB253F99252E 2014-12-05 31595.84
2          OT CENTRAL REGION       CR 8C7149B9EB32EEFC 2014-12-05 28679.06
3          SR CENTRAL REGION       CR C35FEFF02B13E0E5 2014-12-05 29654.96
4          BM CENTRAL REGION       CR 3775D82C5DDBEFBD 2014-12-05 26782.83
5          BM CENTRAL REGION       CR 85D9ABEF0A40678F 2014-12-05 26201.96
6          BM CENTRAL REGION       CR 9D286521EF5E3B59 2014-12-05 25358.82
7          BM CENTRAL REGION       CR 7839A8577144EFE2 2014-12-05 27680.06
8          SR CENTRAL REGION       CR 48661DC0FBA09F7A 2014-12-05 29253.21
9          QT CENTRAL REGION       CR 1F721290C421BFAB 2014-12-05 22077.34
10         QT CENTRAL REGION       CR 3580D2AFFBEE914C 2014-12-05 24168.31
     Y_ADDR SHAPE_Leng SHAPE_Area                       geometry
1  29220.19   5267.381  1630379.3 MULTIPOLYGON (((31495.56 30...
2  29782.05   3506.107   559816.2 MULTIPOLYGON (((29092.28 30...
3  29974.66   1740.926   160807.5 MULTIPOLYGON (((29932.33 29...
4  29933.77   3313.625   595428.9 MULTIPOLYGON (((27131.28 30...
5  30005.70   2825.594   387429.4 MULTIPOLYGON (((26451.03 30...
6  29991.38   4428.913  1030378.8 MULTIPOLYGON (((25899.7 297...
7  30230.86   3275.312   551732.0 MULTIPOLYGON (((27746.95 30...
8  30222.86   2208.619   290184.7 MULTIPOLYGON (((29351.26 29...
9  29893.78   6571.323  1084792.3 MULTIPOLYGON (((20996.49 30...
10 30104.18   3454.239   631644.3 MULTIPOLYGON (((24472.11 29...
```

Notice that only the first ten records will be displayed. Do you know why?

Importing Attribute Data into R

Next, we will import *respopagsex2000to2018.csv* file into RStudio and save the file into an R dataframe called *popagsex*.

The task will be performed by using *read_csv()* function of **readr** package as shown in the code chunk below.

```
popdata <- read_csv("data/aspatial/respopagesextod2011to2020.csv")
```

Data Preparation

Before a thematic map can be prepared, you are required to prepare a data table with year 2020 values. The data table should include the variables PA, SZ, YOUNG, ECONOMY ACTIVE, AGED, TOTAL, DEPENDENCY.

- YOUNG: age group 0 to 4 until age groyup 20 to 24,
- ECONOMY ACTIVE: age group 25-29 until age group 60-64,
- AGED: age group 65 and above,
- TOTAL: all age group, and
- DEPENDENCY: the ratio between young and aged against economy active group

Data wrangling

The following data wrangling and transformation functions will be used:

- *pivot_wider()* of **tidyr** package, and
- *mutate(), filter(), group_by()* and *select()* of **dplyr** package

```
popdata2020 <- popdata %>%
  filter(Time == 2020) %>%
  group_by(PA, SZ, AG) %>%
  summarise(`POP` = sum(`Pop`)) %>%
  ungroup()%>%
  pivot_wider(names_from=AG, 
              values_from=POP) %>%
  mutate(YOUNG = rowSums(.[3:6])
         +rowSums(.[12])) %>%
mutate(`ECONOMY ACTIVE` = rowSums(.[7:11])+
rowSums(.[13:15]))%>%
mutate(`AGED`=rowSums(.[16:21])) %>%
mutate(`TOTAL`=rowSums(.[3:21])) %>%
mutate(`DEPENDENCY` = (`YOUNG` + `AGED`)
/`ECONOMY ACTIVE`) %>%
  select(`PA`, `SZ`, `YOUNG`, 
       `ECONOMY ACTIVE`, `AGED`, 
       `TOTAL`, `DEPENDENCY`)
```

Joining the attribute data and geospatial data

Before we can perform the georelational join, one extra step is required to convert the values in PA and SZ fields to uppercase. This is because the values of PA and SZ fields are made up of upper- and lowercase. On the other, hand the SUBZONE_N and PLN_AREA_N are in uppercase.

```
popdata2020 <- popdata2020 %>%
  mutate_at(.vars = vars(PA, SZ), 
          .funs = funs(toupper)) %>%
  filter(`ECONOMY ACTIVE` > 0)
```

Next, *left_join()* of **dplyr** is used to join the geographical data and attribute table using planning subzone name e.g. *SUBZONE_N* and *SZ* as the common identifier.

```
mpsz_pop2020 <- left_join(mpsz, popdata2020,
                          by = c("SUBZONE_N" = "SZ"))
```

Thing to learn from the code chunk above:

- *left_join()* of **dplyr** package is used with `mpsz` simple feature data frame as the left data table is to ensure that the output will be a simple features data frame.

```
write_rds(mpsz_pop2020, "data/rds/mpszpop2020.rds")
```

Choropleth Mapping Geospatial Data Using *tmap*

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

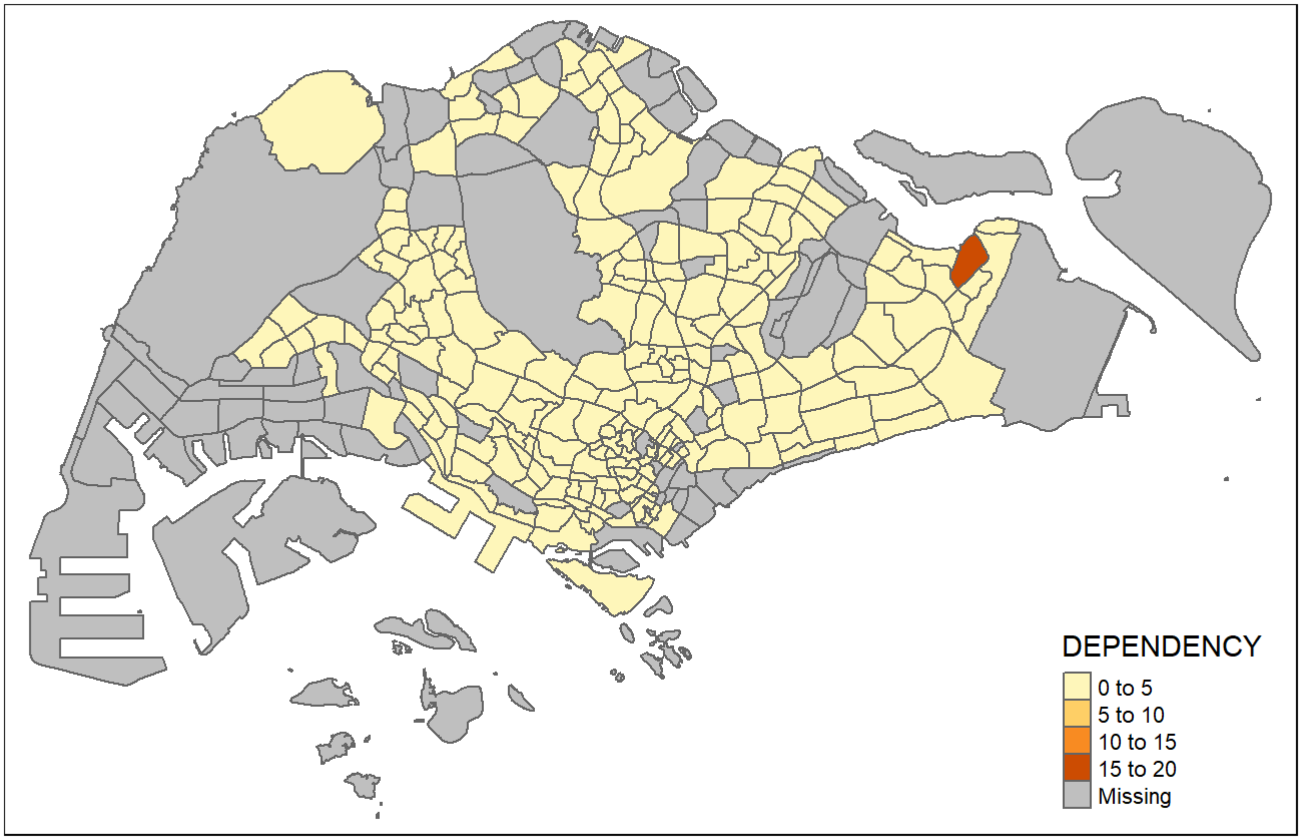
- Plotting a thematic map quickly by using *qtm()*.
- Plotting highly customisable thematic map by using tmap elements.

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.

The code chunk below will draw a cartographic standard choropleth map as shown below.

```
tmap_mode("plot")
qtm(mpsz_pop2020, 
    fill = "DEPENDENCY")
```



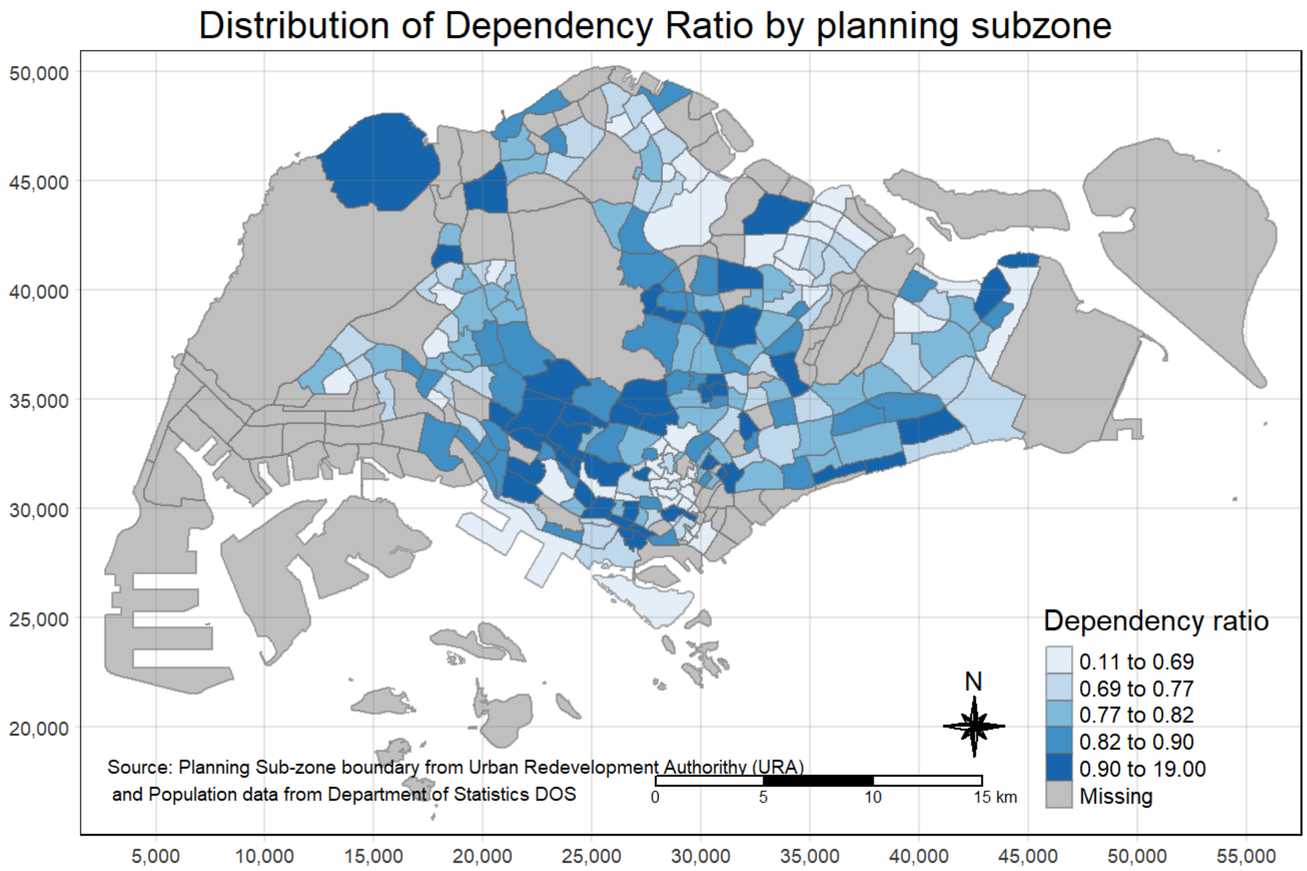
Things to learn from the code chunk above:

- *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)

Creating a choropleth map by using *tmap*'s elements

Despite its usefulness of drawing a choropleth map quickly and easily, the disadvantge of *qtm()* is that it makes aesthetics of individual layers harder to control. To draw a high quality cartographic choropleth map as shown in the figure below, **tmap**'s drawing elements should be used.

```
tm_shape(mpsz_pop2020)+
  tm_fill("DEPENDENCY",
          style = "quantile",
          palette = "Blues",
          title = "Dependency ratio") +
  tm_layout(main.title = "Distribution of Dependency Ratio by planning subzone",
            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() +
  tm_grid(alpha =0.2) +
  tm_credits("Source: Planning Sub-zone boundary from Urban Redevelopment Authorithy (URA)\n and F
             position = c("left", "bottom"))
```



In the following sub-section, we will share with you tmap functions that used to plot these elements.

Drawing a base map

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

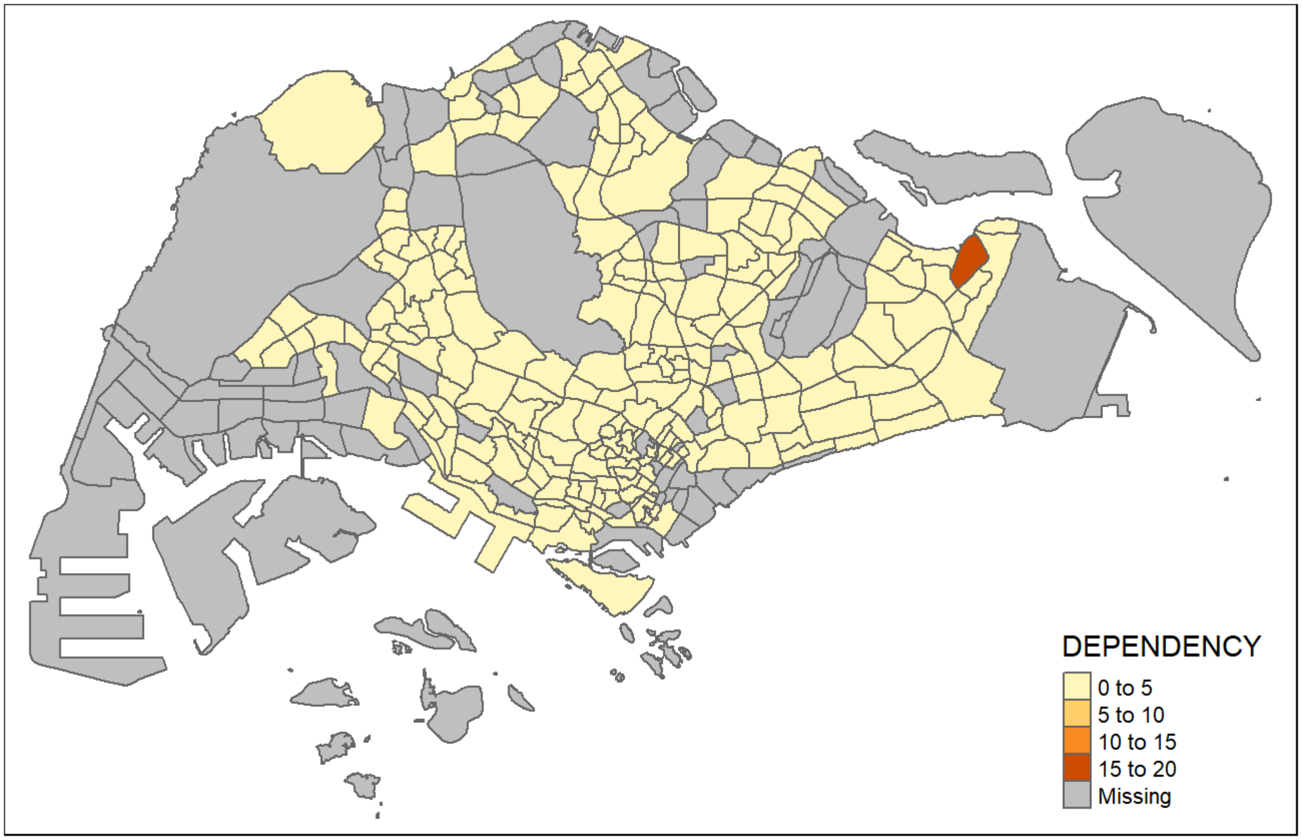
In the code chunk below, *tm_shape()* is used to define the input data (i.e *mpsz_pop2020*) and *tm_polygons()* is used to draw the planning subzone polygons

```
tm_shape(mpsz_pop2020) +
  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(mpsz_pop2020)+
  tm_polygons("DEPENDENCY")
```



Things to learn from *tm_polygons()*:

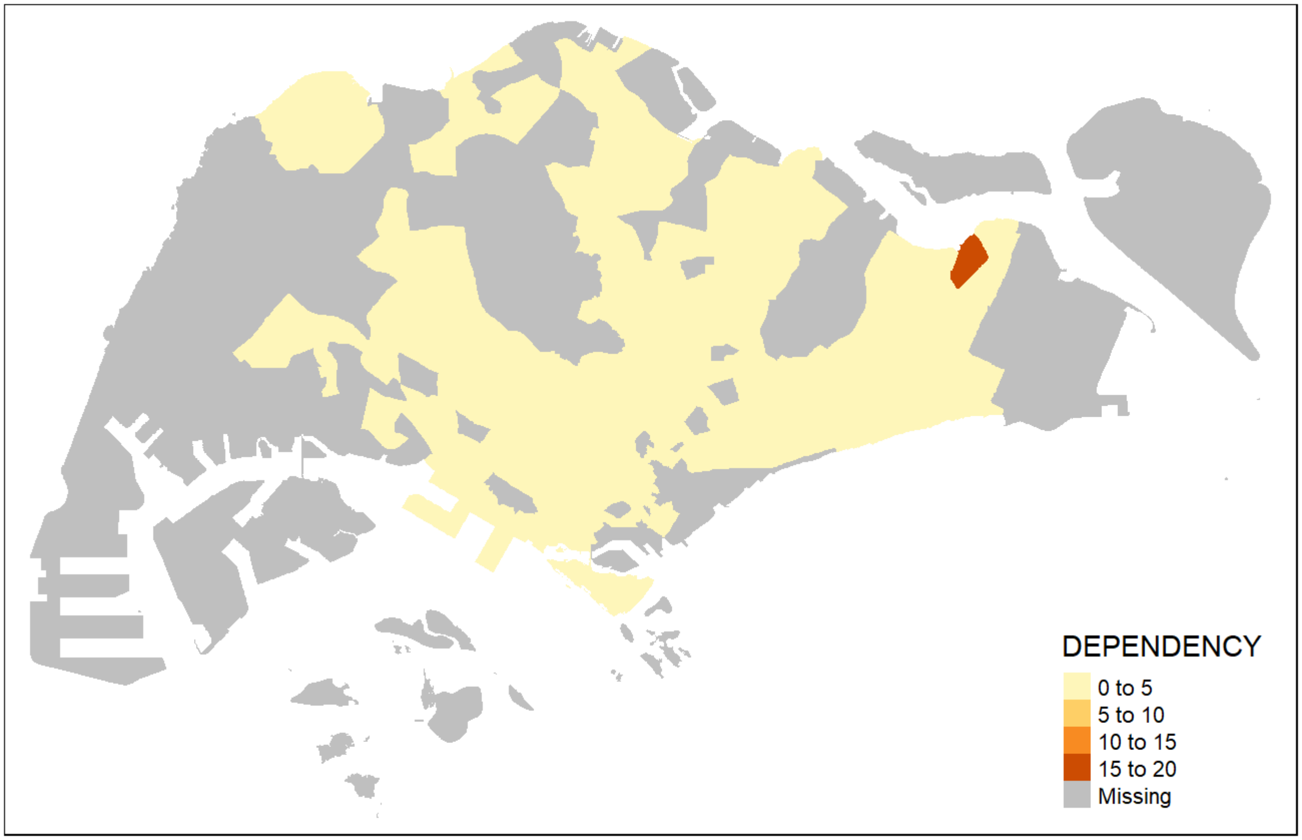
- The default interval binning used to draw the choropleth map is called "pretty". A detailed discussion of the data classification methods supported by **tmap** will be provided in sub-section 4.3.
- The default colour scheme used is `YlOrRd` of ColorBrewer. You will learn more about the color scheme in sub-section 4.4.
- By default, Missing value will be shaded in grey.

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

Actually, *tm_polygons()* is a wraper of *tm_fill()* and *tm_border()*. *tm_fill()* shades the polygons by using the default colour scheme and *tm_borders()* adds the borders of the shapefile onto the choropleth map.

The code chunk below draws a choropleth map by using *tm_fill()* alone.

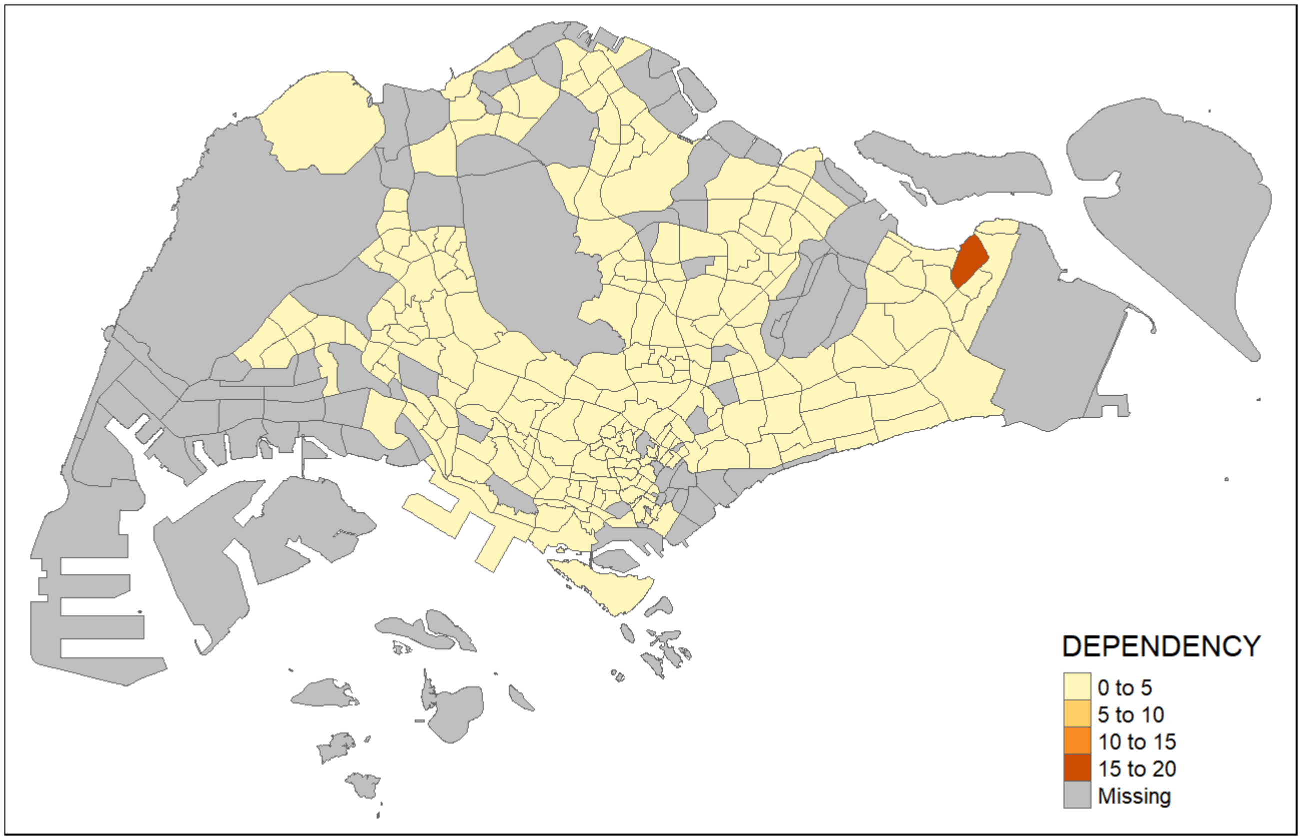
```
tm_shape(mpsz_pop2020)+
  tm_fill("DEPENDENCY")
```



Notice that the planning subzones are shared according to the respective dependecy values

To add the boundary of the planning subzones, tm_borders will be used as shown in the code chunk below.

```
tm_shape(mpsz_pop2020)+
  tm_fill("DEPENDENCY") +
  tm_borders(lwd = 0.1,  alpha = 1)
```



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

The *alpha* argument is used to define transparency number between 0 (totally transparent) and 1 (not transparent). By default, the alpha value of the col is used (normally 1).

Beside *alpha* argument, there are three other arguments for *tm_borders()*, they are:

- *col* = border colour,
- *lwd* = border line width. The default is 1, and
- *lty* = border line type. The default is "solid".

Data classification methods of **tmap**

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

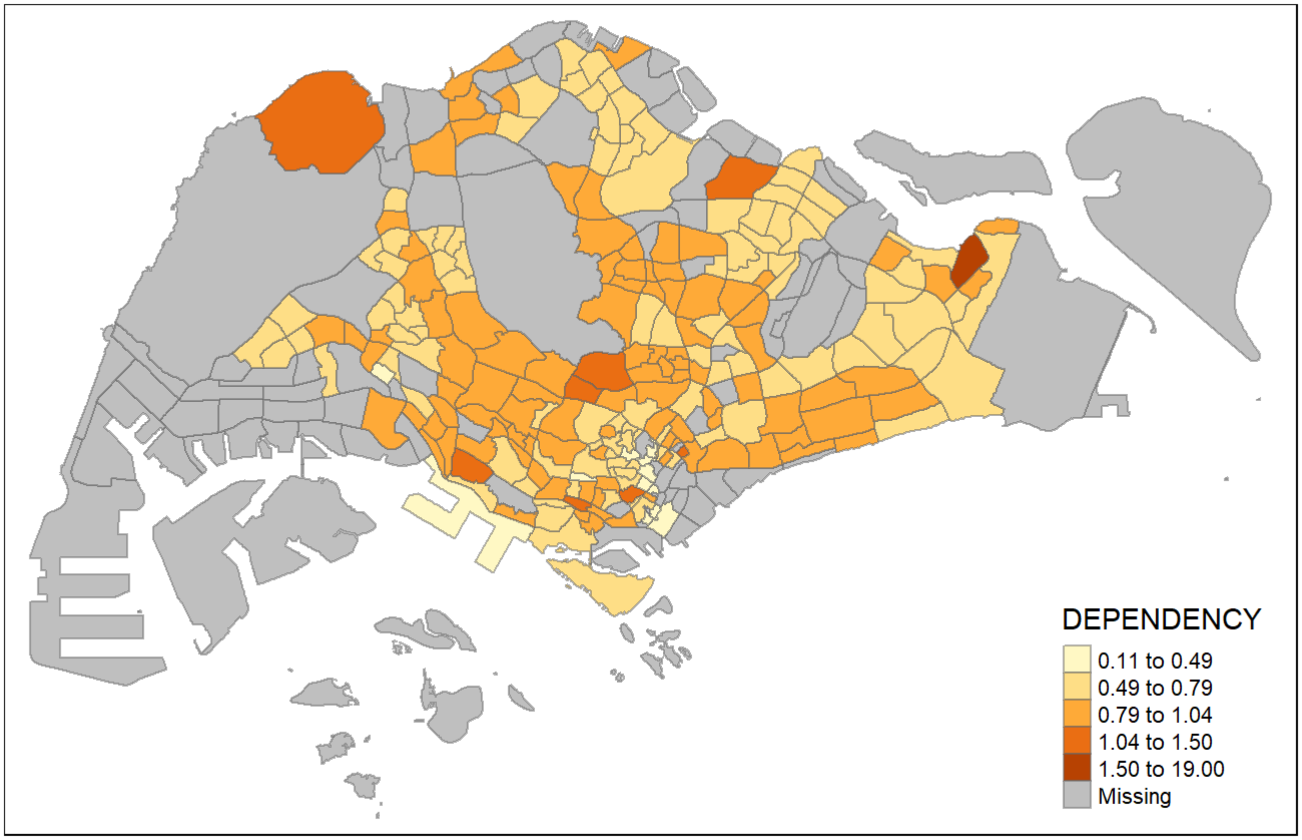
tmap provides a total ten data classification methods, namely: *fixed*, *sd*, *equal*, *pretty* (default), *quantile*, *kmeans*, *hclust*, *bclust*, *fisher*, and *jenks*.

To define a data classification method, the *style* argument of *tm_fill()* or *tm_polygons()* will be used.

Plotting choropleth maps with built-in classification methods

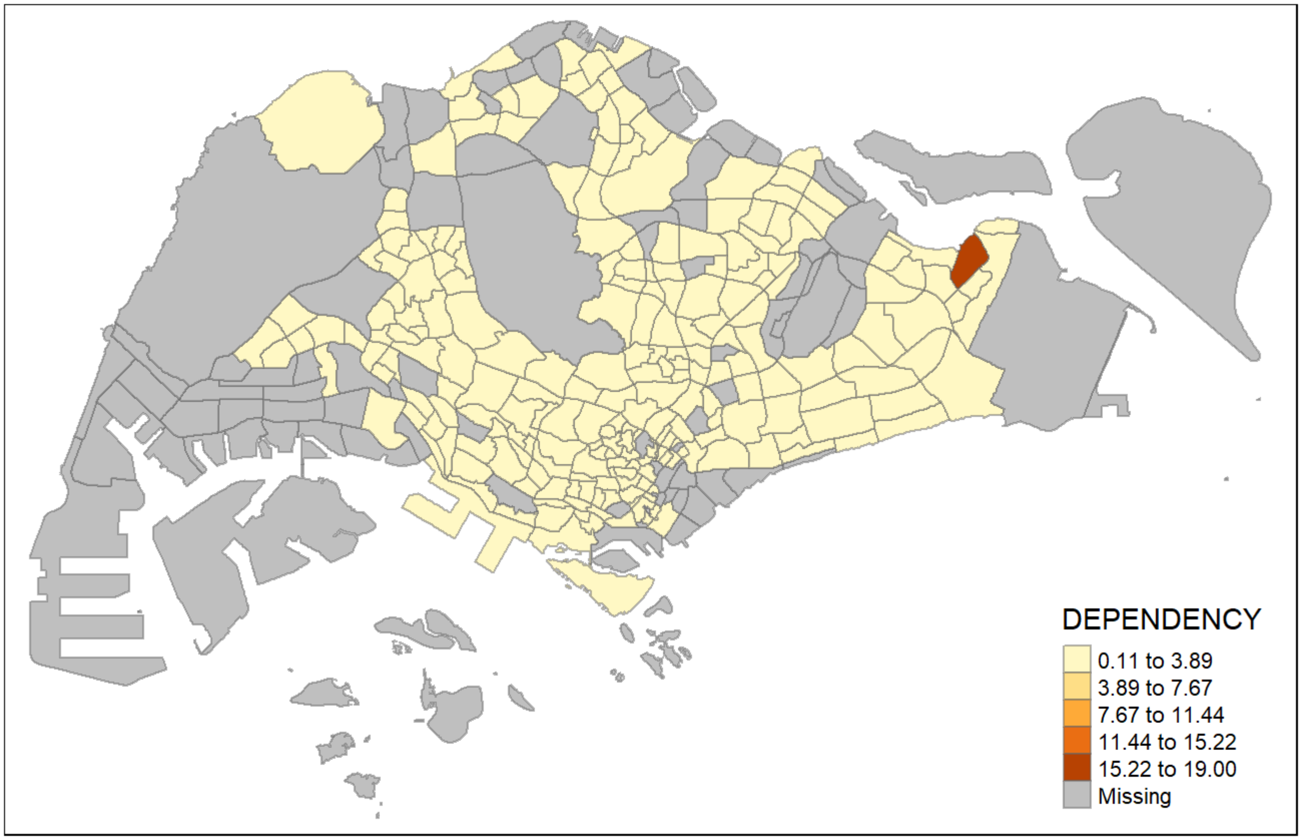
The code chunk below shows a quantile data classification that used 5 classes.

```
tm_shape(mpsz_pop2020)+
  tm_fill("DEPENDENCY",
          n = 5,
          style = "jenks") +
  tm_borders(alpha = 0.5)
```



In the code chunk below, *equal* data classification method is used.

```
tm_shape(mpsz_pop2020)+
  tm_fill("DEPENDENCY",
          n = 5,
          style = "equal") +
  tm_borders(alpha = 0.5)
```



Notice that the distribution of quantile data classification method are more evenly distributed then equal data classification method.

> **Warning: Maps Lie!**

> DIY: Using what you had learned, prepare choropleth maps by using different classification methods supported by tmap and compare their differences.

> DIY: Preparing choropleth maps by using similar classification method but with different numbers of classes (i.e. 2, 6, 10, 20). Compare the output maps, what observation can you draw?

Plotting choropleth map with custome break

For all the built-in styles, the category breaks are computed internally. In order to override these defaults, the breakpoints can be set explicitly by means of the *breaks* argument to the *tm_fill()*. It is important to note that, in **tmap** the breaks include a minimum and maximum. As a result, in order to end up with n categories, n+1 elements must be specified in the *breaks* option (the values must be in increasing order).

Before we get started, it is always a good practice to get some descriptive statistics on the variable before setting the break points. Code chunk below will be used to compute and display the descriptive statistics of **DEPENDENCY** field.

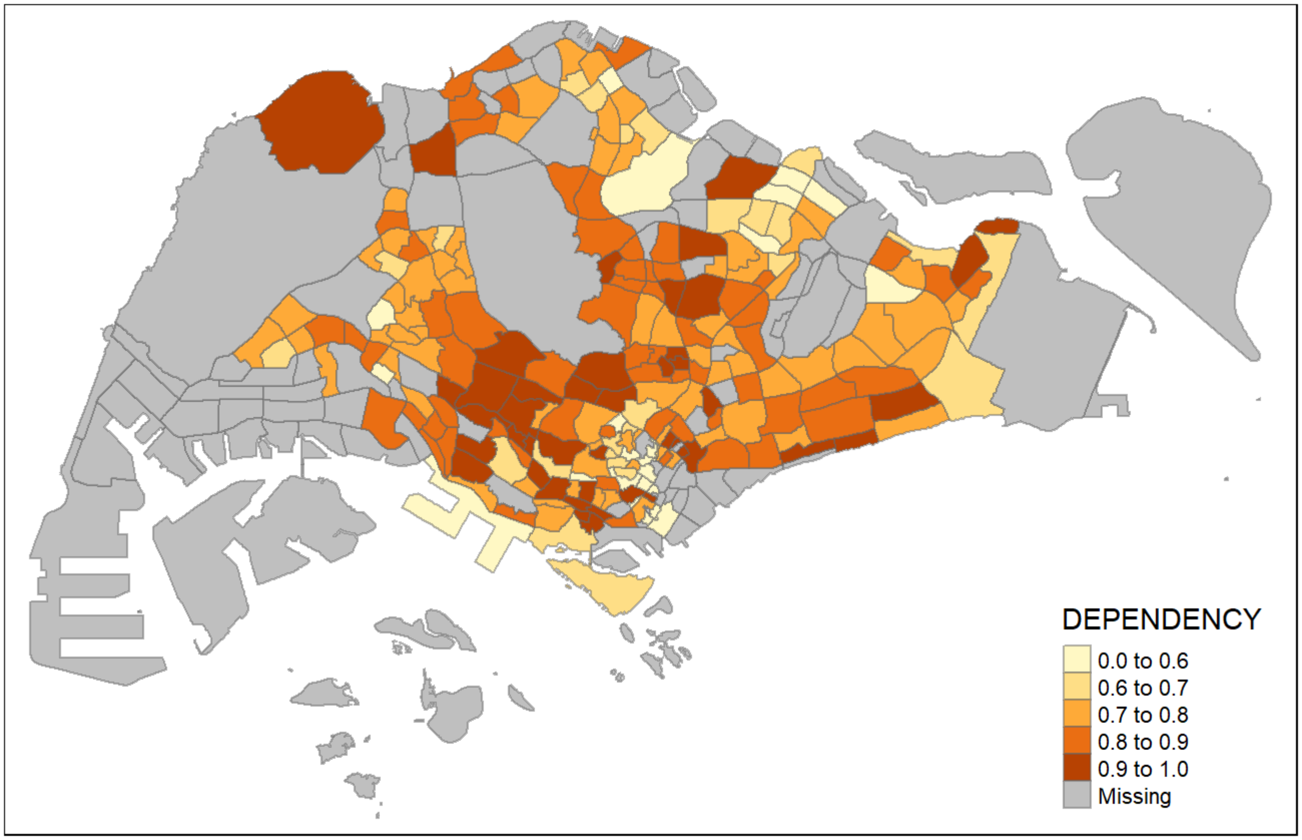
```r
summary(mpsz_pop2020$DEPENDENCY)
```

```
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.    NA's 
 0.1111  0.7147  0.7866  0.8585  0.8763 19.0000      92 
```

With reference to the results above, we set break point at 0.60, 0.70, 0.80, and 0.90. In addition, we also need to include a minimum and maximum, which we set at 0 and 100. Our *breaks* vector is thus c(0, 0.60, 0.70, 0.80, 0.90, 1.00)

Now, we will plot the choropleth map by using the code chunk below.

```r
tm_shape(mpsz_pop2020)+
  tm_fill("DEPENDENCY",
          breaks = c(0, 0.60, 0.70, 0.80, 0.90, 1.00)) +
  tm_borders(alpha = 0.5)
```



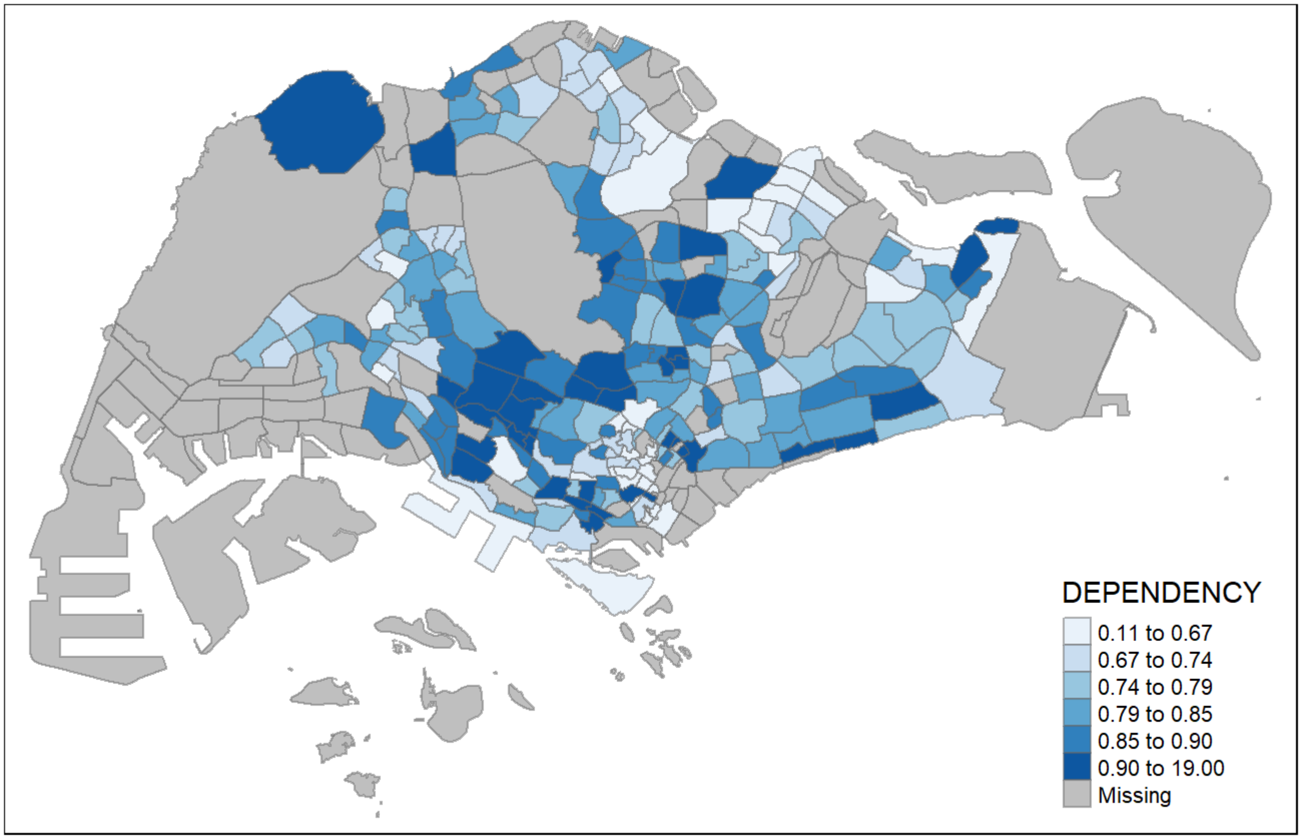
Colour Scheme

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

Using ColourBrewer palette

To change the colour, we assign the preferred colour to *palette* argument of *tm_fill()* as shown in the code chunk below.

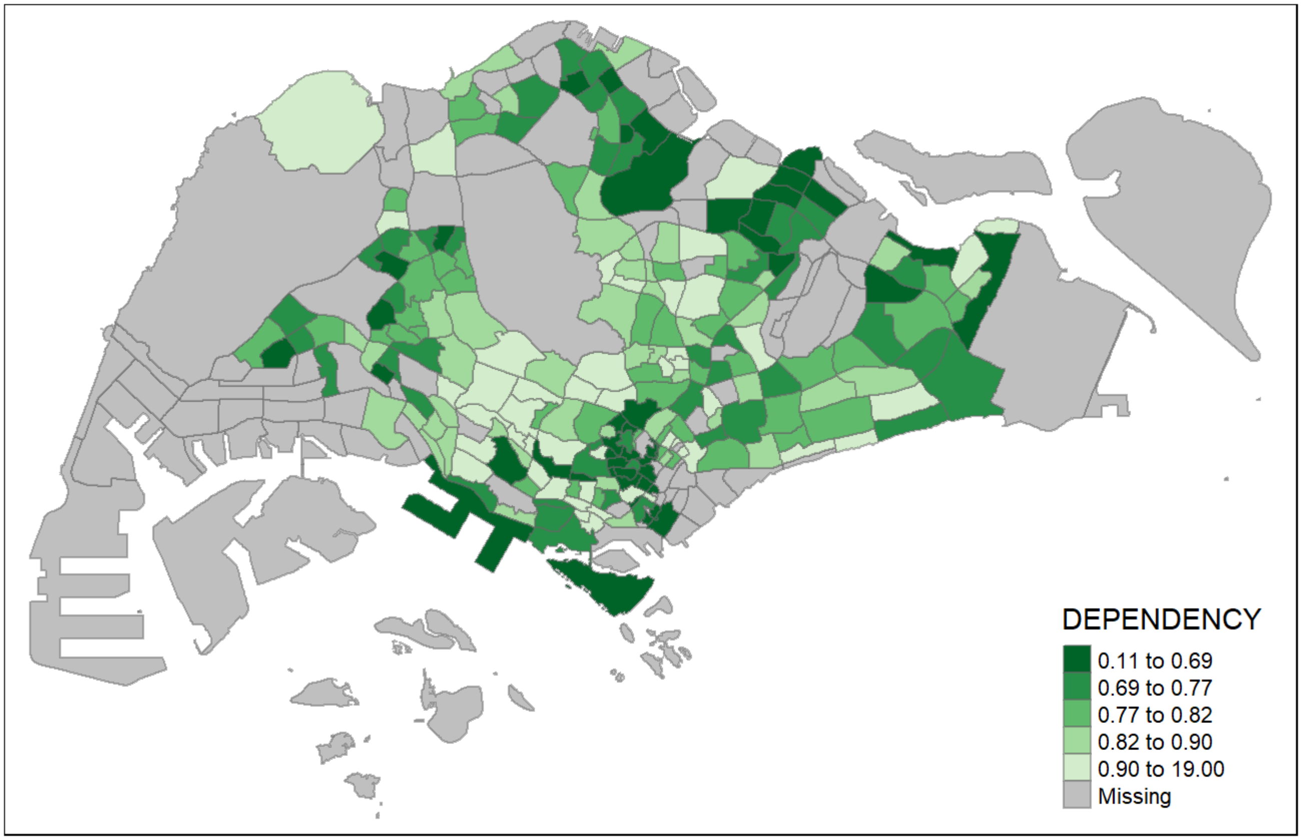
```
tm_shape(mpsz_pop2020)+
  tm_fill("DEPENDENCY",
          n = 6,
          style = "quantile",
          palette = "Blues") +
  tm_borders(alpha = 0.5)
```



Notice that the choropleth map is shaded in green.

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

```
tm_shape(mpsz_pop2020)+
  tm_fill("DEPENDENCY",
          style = "quantile",
          palette = "-Greens") +
  tm_borders(alpha = 0.5)
```



Notice that the colour scheme has been reversed.

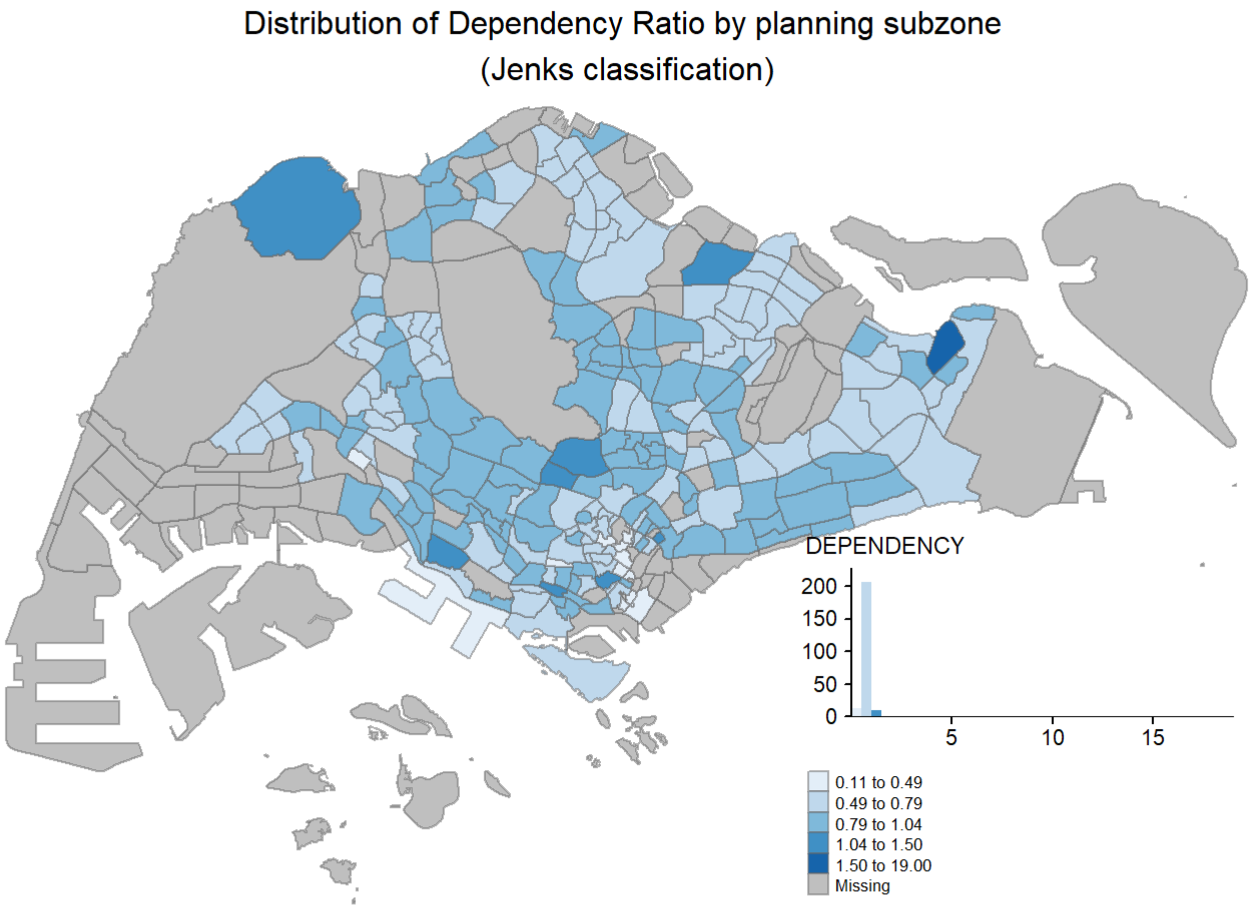
Map Layouts

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. Colour settings and data classification methods covered in the previous section relate to the palette and break-points are used to affect how the map looks.

Map Legend

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

```
tm_shape(mpsz_pop2020)+
  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 Dependency Ratio by planning subzone \n(Jenks classifica
            main.title.position = "center",
            main.title.size = 1,
            legend.height = 0.45,
            legend.width = 0.35,
            legend.outside = FALSE,
            legend.position = c("right", "bottom"),
            frame = FALSE) +
  tm_borders(alpha = 0.5)
```

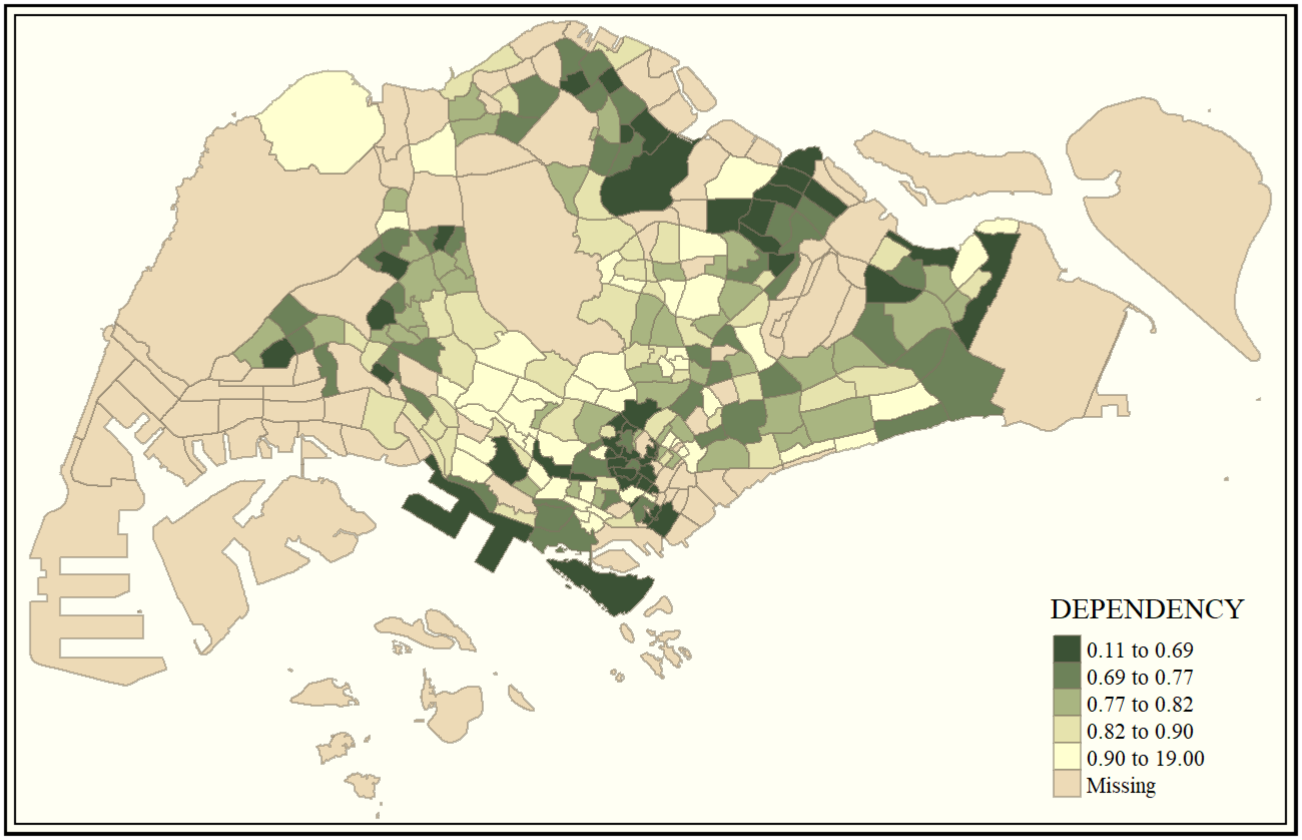


Map style

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

The code chunk below shows the *classic* style is used.

```
tm_shape(mpsz_pop2020)+
  tm_fill("DEPENDENCY",
          style = "quantile",
          palette = "-Greens") +
  tm_borders(alpha = 0.5) +
  tmap_style("classic")
```

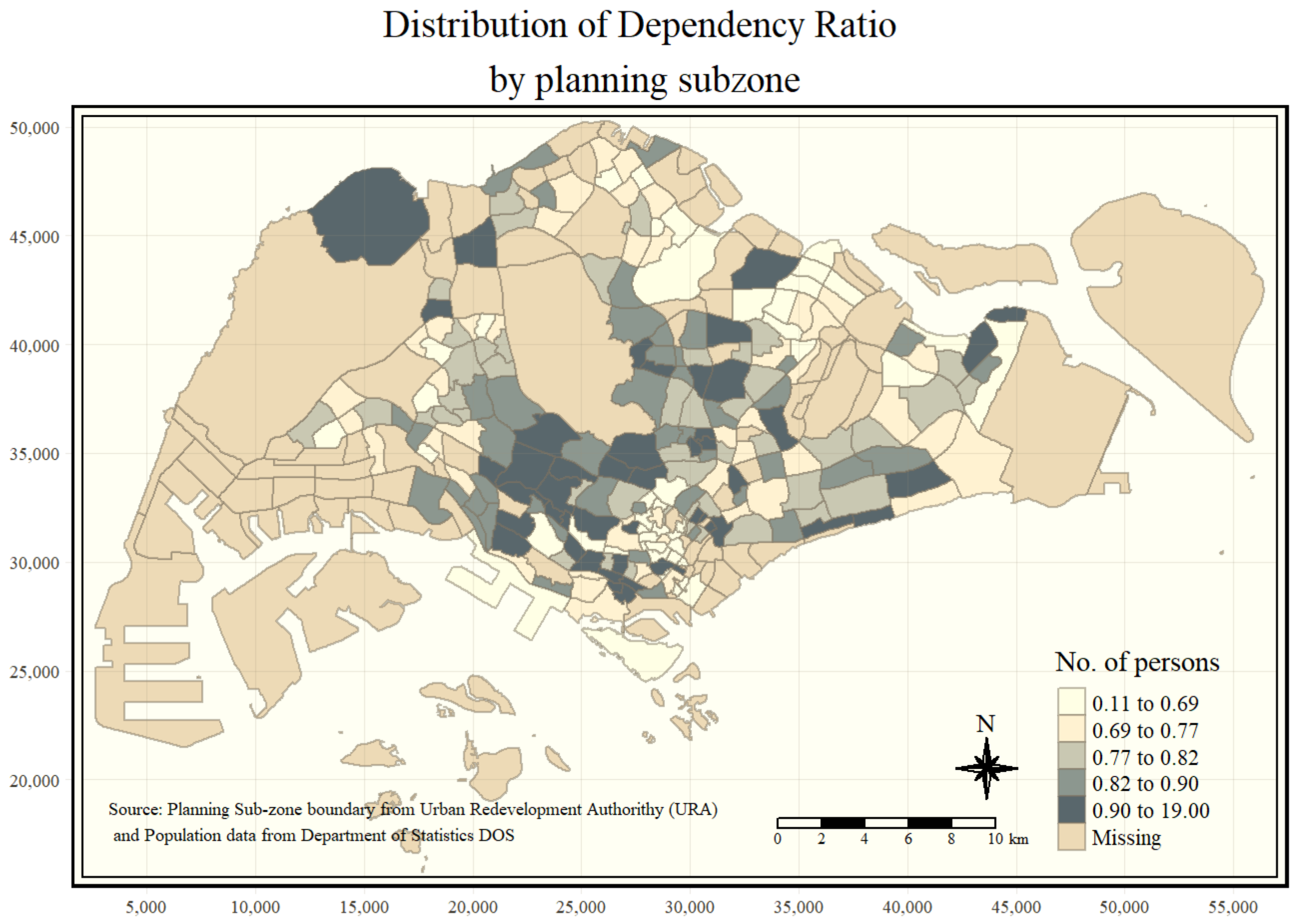


Cartographic Furniture

Beside map style, **tmap** also also provides arguments to draw other map furniture such as compass, scale bar and grid lines.

In the code chunk 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(mpsz_pop2020)+
  tm_fill("DEPENDENCY",
          style = "quantile",
          palette = "Blues",
          title = "No. of persons") +
  tm_layout(main.title = "Distribution of Dependency Ratio \nby planning subzone",
            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) +
  tm_credits("Source: Planning Sub-zone boundary from Urban Redevelopment Authorithy (URA)\n and P
             position = c("left", "bottom"))
```



To reset the default style, refer to the code chunk below.

```
tmap_style("white")
```

Drawing Small Multiple Choropleth Maps

Small multiple maps, also referred to as **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.

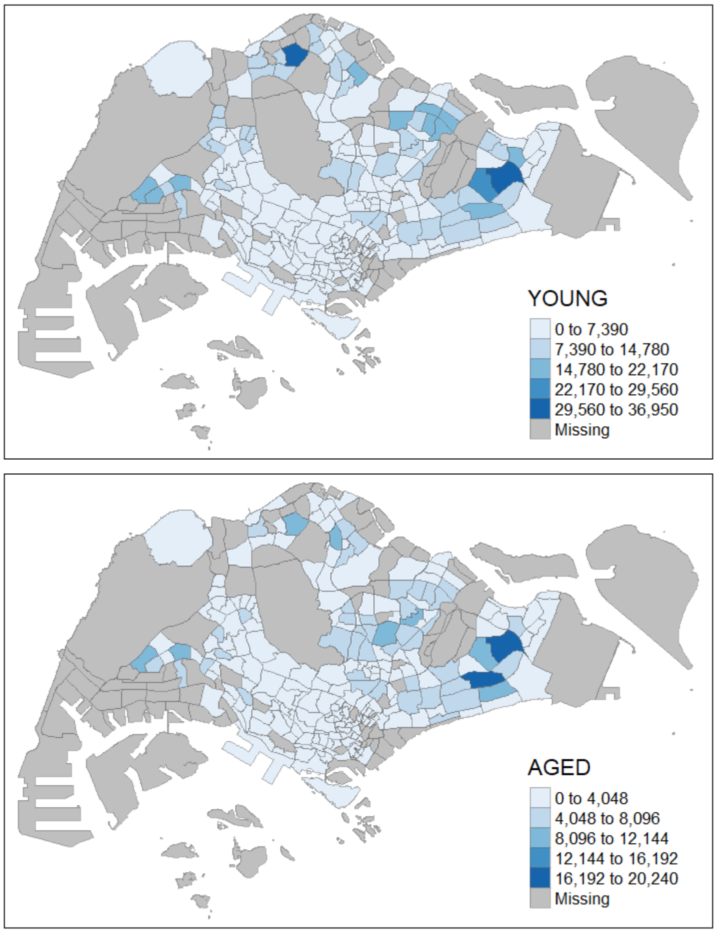
In **tmap**, small multiple maps can be plotted in three ways:

- 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

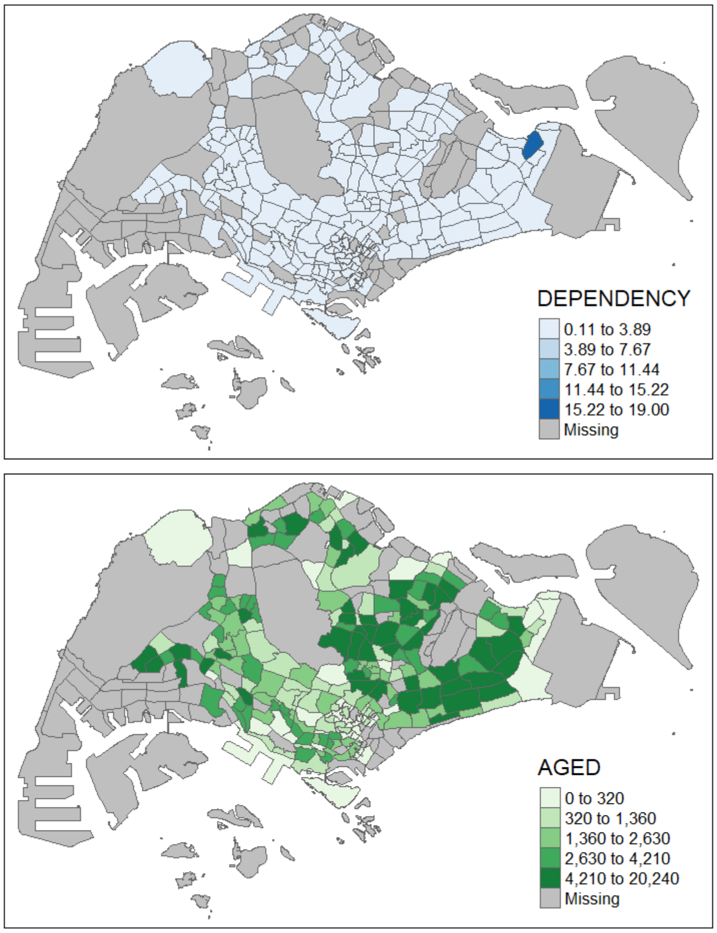
In this example, small multiple choropleth maps are created by defining ***ncols*** in **tm_fill()**

```
tm_shape(mpsz_pop2020)+
  tm_fill(c("YOUNG", "AGED"),
          style = "equal",
          palette = "Blues") +
  tm_layout(legend.position = c("right", "bottom")) +
  tm_borders(alpha = 0.5) +
  tmap_style("white")
```



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

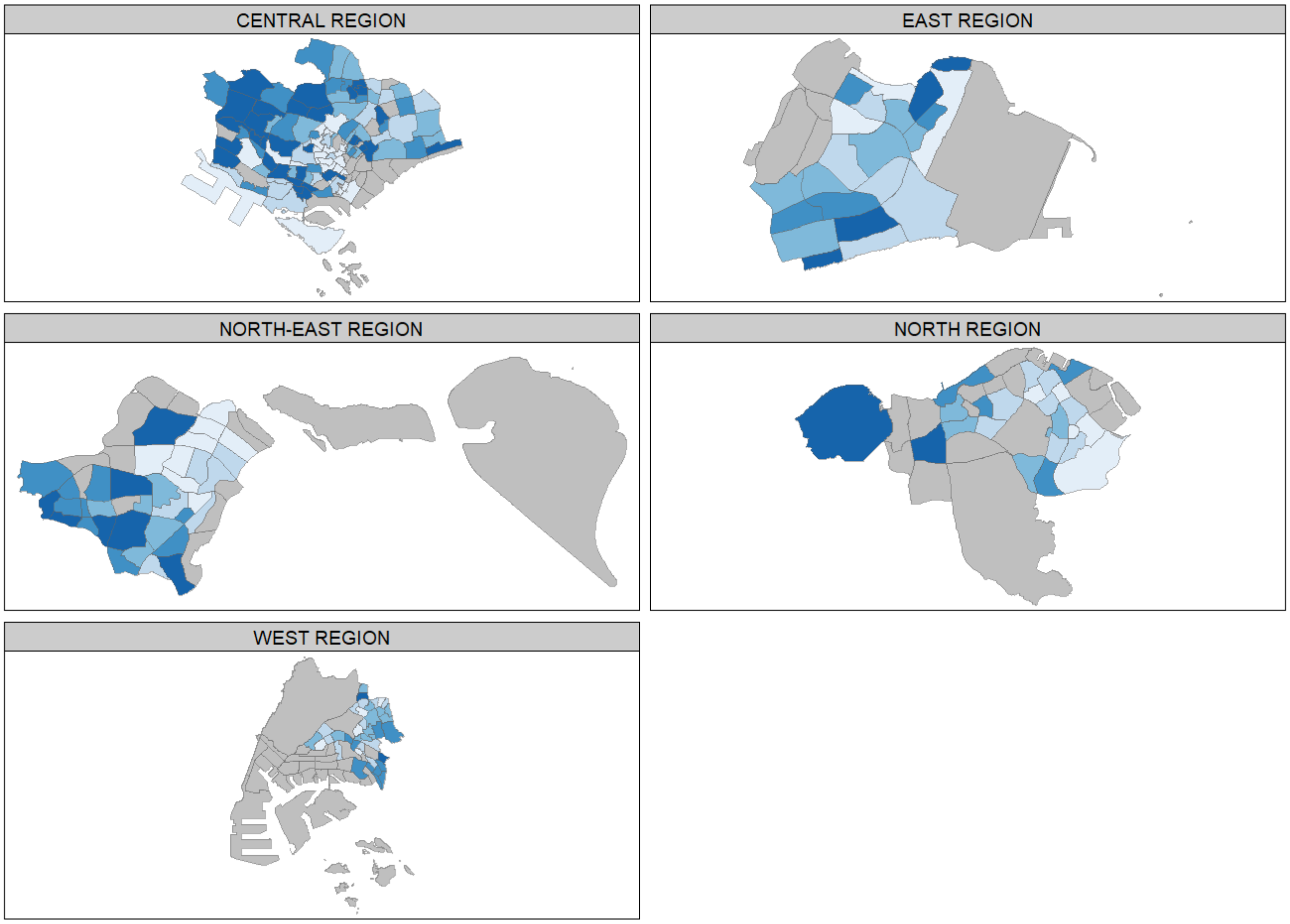
```
tm_shape(mpsz_pop2020)+
  tm_polygons(c("DEPENDENCY","AGED"),
          style = c("equal", "quantile"),
          palette = list("Blues","Greens")) +
  tm_layout(legend.position = c("right", "bottom"))
```



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

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

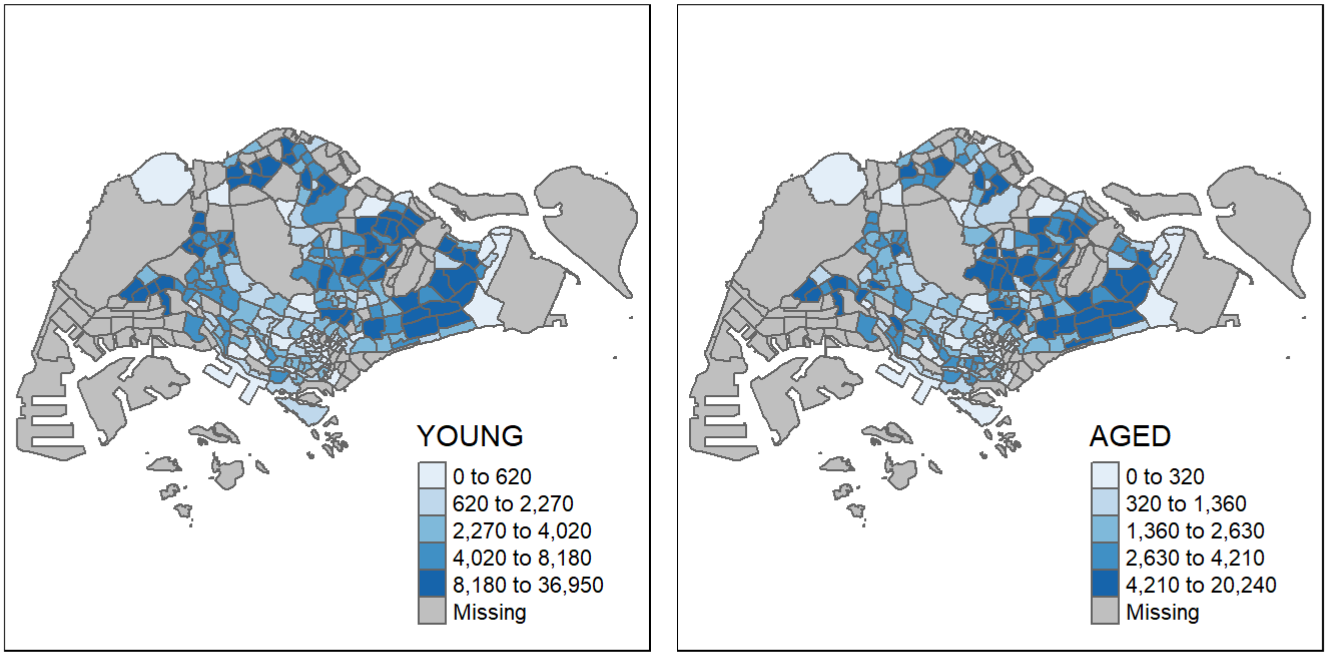
```
tm_shape(mpsz_pop2020) +
  tm_fill("DEPENDENCY",
          style = "quantile",
          palette = "Blues",
          thres.poly = 0) +
  tm_facets(by="REGION_N",
            free.coords=TRUE,
            drop.shapes=TRUE) +
  tm_layout(legend.show = FALSE,
            title.position = c("center", "center"),
            title.size = 20) +
  tm_borders(alpha = 0.5)
```



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()**.

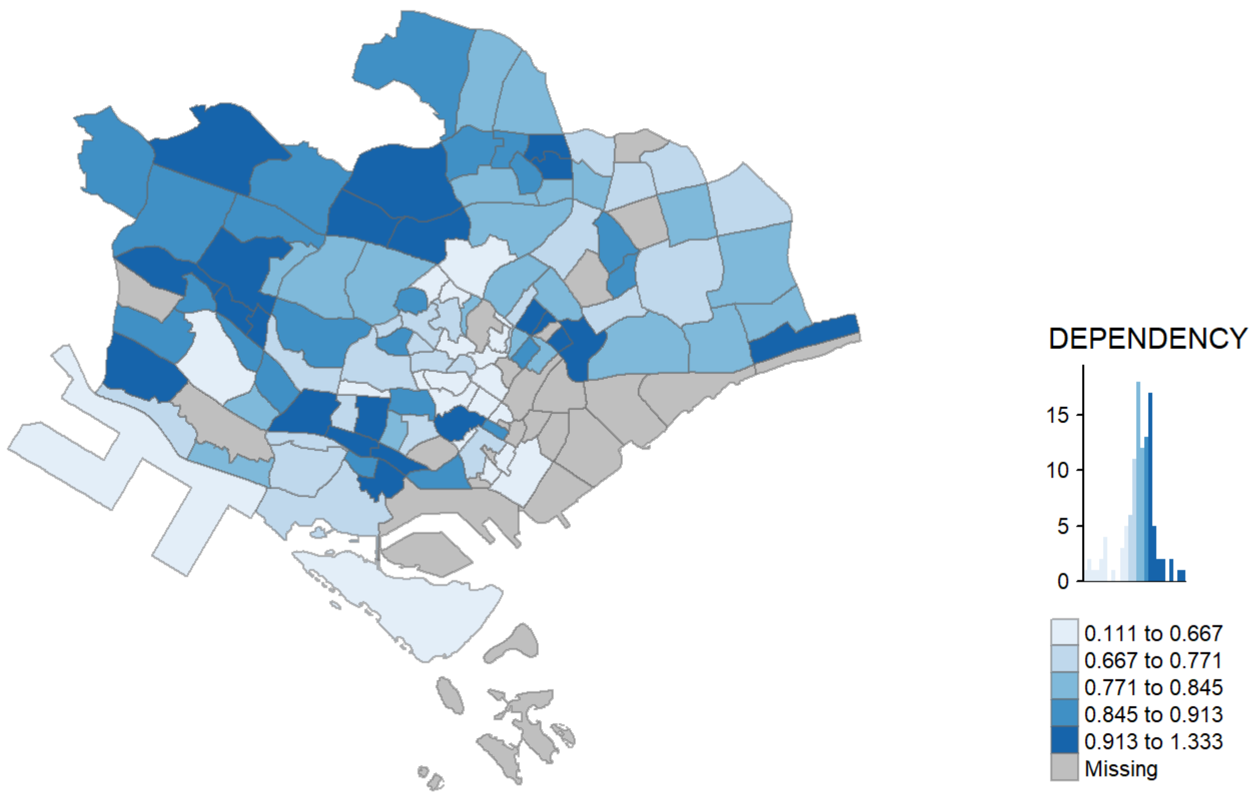
```
youngmap <- tm_shape(mpsz_pop2020)+
  tm_polygons("YOUNG",
              style = "quantile",
              palette = "Blues")

agedmap <- tm_shape(mpsz_pop2020)+
  tm_polygons("AGED",
              style = "quantile",
              palette = "Blues")

tmap_arrange(youngmap, agedmap, asp=1, ncol=2)
```



Mapppping Spatial Object Meeting a Selection Criterion

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

```
tm_shape(mpsz_pop2020[mpsz_pop2020$REGION_N=="CENTRAL REGION", ])+
  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

All about **tmap** package

- tmap: Thematic Maps in R
- tmap
- tmap: get started!
- tmap: changes in version 2.0
- tmap: creating thematic maps in a flexible way (useR!2015)
- Exploring and presenting maps with tmap (useR!2017)

Geospatial data wrangling

- sf: Simple Features for R
- Simple Features for R: StandardizedSupport for Spatial Vector Data
- Reading, Writing and Converting Simple Features

Data wrangling

- dplyr
- Tidy data

- tidyr: Easily Tidy Data with ‘spread()’ and ‘gather()’ Functions