Initial considerations

A disadvantage of choropleth maps is that they tend to distort the relationship between the true underlying geography and the represented variable. It is because the administrative divisions do not usually coincide with the geographical reality where people live. Besides, large areas appear to have a weight that they do not really have because of sparsely populated regions. To better reflect reality, more realistic population distributions are used, such as land use. With Geographic Information Systems techniques, it is possible to redistribute the variable of interest as a function of a variable with a smaller spatial unit.

With point data, the redistribution process is simply clipping points with population based on land use, usually classified as urban. We could also crop and mask with land use polygons when we have a vectorial polygon layer, but an interesting alternative is the same data in raster format. We will see how we can make a dasymetric map using raster data with a resolution of 100 m. This post will use data from census sections of the median income and the Gini index for Spain. We will make a dasymetric and bivariate map, representing both variables with two ranges of colours on the same map.

Packages

In this post we will use the following packages:

Package	Description
tidyverse	Collection of packages (visualization, manipulation): ggplot2, dplyr, purrr, etc.
patchwork	Simple grammar to combine separate ggplots into the same graphic
raster	Import, export and manipulate raster
sf	Simple Feature: import, export and manipulate vector data
biscale	Tools and Palettes for Bivariate Thematic Mapping
sysfonts	Load fonts in R
showtext	Use fonts more easily in R graphs

```
# install the packages if necessary
if(!require("tidyverse")) install.packages("tidyverse")
if(!require("patchwork")) install.packages("patchwork")
if(!require("sf")) install.packages("sf")
if(!require("raster")) install.packages("raster")
if(!require("biscale")) install.packages("biscale")
if(!require("sysfonts")) install.packages("sysfonts")
if(!require("showtext")) install.packages("showtext")

# packages
library(tidyverse)
library(sf)
library(readxl)
library(biscale)
library(patchwork)
library(raster)
library(sysfonts)
library(showtext)
```

```
library(raster)
```

Preparation

Data

First we download all the necessary data. With the exception of the CORINE Land Cover (~ 200 MB), the data stored on this blog can be obtained directly via the indicated links.

- CORINE Land Cover 2018 (geotiff): COPERNICUS
- Income data and Gini index (excel) [INE]: download
- Census limits of Spain (vectorial) [INE]: download

Import

The first thing we do is to import the land use raster, the income and Gini index data, and the census boundaries.

```
# raster of CORINE LAND COVER 2018
urb <- raster("U2018_CLC2018_V2020_20u1.tif")
## Warning in showSRID(uprojargs, format = "PROJ", multiline = "NO",
prefer_proj
## = prefer_proj): Discarded datum Unknown based on GRS80 ellipsoid in
Proj4
## definition
# income data and Gini index
renta <- read_excel("30824.xlsx")
gini <- read_excel("37677.xlsx")

# census boundaries
limits <- read_sf("SECC_CE_20200101.shp")
```

Land uses

In this first step we filter the census sections to obtain those of the Autonomous Community of Madrid, and we create the municipal limits. To dissolve the polygons of census tracts we apply the function `group_by()` in combination with `summarise()`.

```
# filter the Autonomous Community of Madrid
limits <- filter(limits, NCA == "Comunidad de Madrid")

# obtain the municipal limits
mun_limit <- group_by(limits, CUMUN) %>% summarise()
```

In the next step we cut the land use raster with the limits of Madrid. I recommend always using the `crop()` function first and then `mask()`, the first function crop to the required extent and the second mask the values. Subsequently, we remove all the cells that correspond to 1 or 2 (urban continuous, discontinuous). Finally, we project the raster.

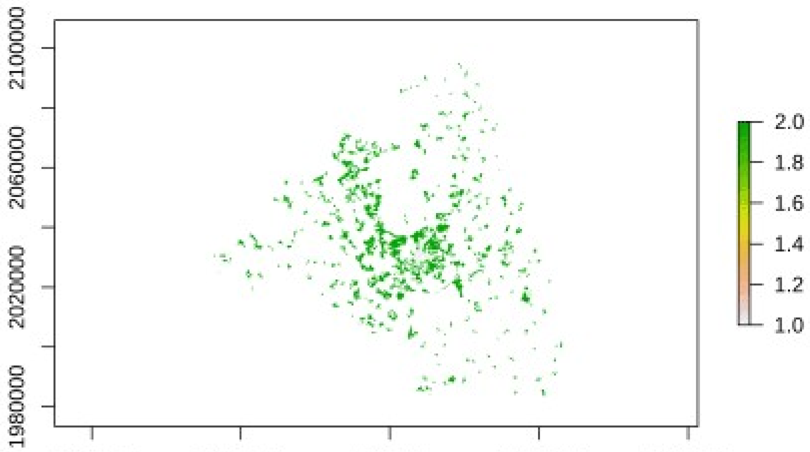
```
# project the limits
limits_prj <- st_transform(limits, projection(urb))

# crop and mask
urb_mad <- crop(urb, limits_prj) %>%
```

```
              mask(limits_prj)

# remove non-urban pixels
urb_mad[!urb_mad %in% 1:2] <- NA

# plot the raster
plot(urb_mad)
```




```
# project
urb_mad <- projectRaster(urb_mad, crs = CRS("+proj=longlat +datum=WGS84
+no_defs"))
```

In this step, we convert the raster data into a point `sf` object.

```
# transform the raster to xyz and a sf object
urb_mad <- as.data.frame(urb_mad, xy = TRUE, na.rm = TRUE) %>%
                st_as_sf(coords = c("x", "y"), crs = 4326)

# add the columns of the coordinates
urb_mad <- urb_mad %>% rename(urb = 1) %>%
cbind(st_coordinates(urb_mad))
```

Income data and Gini index

The format of the Excels does not coincide with the original of the INE, since I have cleaned the format before in order to make this post easier. What remains is to create a column with the codes of the census sections and exclude data that correspond to another administrative level.

```
## income and Gini index data

renta_sec <- mutate(renta, NATCODE = str_extract(CUSEC, "[0-9]{5,10}"),
                nc_len = str_length(NATCODE),
                mun_name = str_remove(CUSEC, NATCODE) %>% str_trim())
%>%
             filter(nc_len > 5)
```

```
gini_sec <- mutate(gini, NATCODE = str_extract(CUSEC, "[0-9]{5,10}"),
               nc_len = str_length(NATCODE),
               mun_name = str_remove(CUSEC, NATCODE) %>% str_trim())
%>%
             filter(nc_len > 5)
```

In the next step we join both tables with the census tracts using `left_join()` and convert columns of interest in numerical mode.

```
# join both the income and Gini tables with the census limits
mad <- left_join(limits, renta_sec, by = c("CUSEC"="NATCODE")) %>%
          left_join(gini_sec, by = c("CUSEC"="NATCODE"))

# convert selected columns to numeric
mad <- mutate_at(mad, c(23:27, 30:31), as.numeric)
```

Bivariate variable

To create a bivariate map we must construct a single variable that combines different classes of two variables. Usually we make three classes of each variable which leads to nine combinations; in our case, the average income and the Gini index. The `biscale` package includes helper functions to carry out this process. With the `bi_class()` function we create the classification variable using quantiles as algorithm. Since in both variables we find missing values, we correct those combinations between both variables where an `NA` appears.

```
# create bivariate classification
mapbivar <- bi_class(mad, GINI_2017, RNMP_2017, style = "quantile", dim
= 3) %>%
             mutate(bi_class = ifelse(str_detect(bi_class, "NA"), NA,
bi_class))

# results
head(dplyr::select(mapbivar, GINI_2017, RNMP_2017, bi_class))
## Simple feature collection with 6 features and 3 fields
## geometry type:  MULTIPOLYGON
## dimension:      XY
## bbox:           xmin: 415538.9 ymin: 4451487 xmax: 469341.7 ymax:
4552422
## projected CRS:  ETRS89 / UTM zone 30N
## # A tibble: 6 x 4
##   GINI_2017 RNMP_2017 bi_class
geometry
##
## 1      NA          NA      (((446007.9 4552348, 446133.7 4552288,
446207.8 ~
## 2      31       13581 2-2      (((460243.8 4487756, 460322.4
4487739, 460279 44~
## 3      30       12407 2-2      (((457392.5 4486262, 457391.6
4486269, 457391.1 ~
## 4      34.3     13779 3-2      (((468720.8 4481374, 468695.5
4481361, 468664.6 ~
## 5      33.5      9176 3-1      (((417140.2 4451736, 416867.5
```

```
4451737, 416436.8 ~
## 6      26.2     10879 1-1      (((469251.9 4480826, 469268.1
4480797, 469292.6 ~
```

We finish by redistributing the inequality variable over the pixels of urban land use. The `st_join()` function joins the data with the land use points.

```
# redistribute urban pixels to inequality
mapdasi <- st_join(urb_mad, st_transform(mapbivar, 4326))
```

Map building

Legend and font

Before constructing both maps we must create the legend using the `bi_legend()` function. In the function we define the titles for each variable, the number of dimensions and the color scale. Finally, we add the Montserrat font for the final titles in the graphic.

```
# bivariate legend
legend2 <- bi_legend(pal = "DkViolet",
                     dim = 3,
                     xlab = "Higher inequality",
                     ylab = "Higher income",
                     size = 9)



# download font
font_add_google("Montserrat", "Montserrat")
showtext_auto()
```

Dasymetric map

We build this map using `geom_tile()` for the pixels and `geom_sf()` for the municipal boundaries. In addition, it will be the map on the right where we also place the legend. To add the legend we use the `annotation_custom()` function indicating the position in the geographical coordinates of the map. The `biscale` package also helps us with the color definition via the `bi_scale_fill()` function.

```
p2 <- ggplot(mapdasi) +
  geom_tile(aes(X, Y,
                fill = bi_class),
            show.legend = FALSE) +
  geom_sf(data = mun_limit,
          color = "grey80",
          fill = NA,
          size = 0.2) +
  annotation_custom(ggplotGrob(legend2),
                    xmin = -3.25, xmax = -2.65,
                    ymin = 40.55, ymax = 40.95) +
  bi_scale_fill(pal = "DkViolet",
                dim = 3,
                na.value = "grey90") +
  labs(title = "dasymetric", x = "", y ="") +
```

```
  bi_theme() +
  theme(plot.title = element_text(family = "Montserrat", size = 30,
face = "bold")) +
  coord_sf(crs = 4326)
```

Choropleth map

The choropleth map is built in a similar way to the previous map with the difference that we use `geom_sf()`.

```
p1 <- ggplot(mapbivar) +
  geom_sf(aes(fill = bi_class),
          colour = NA,
          size = .1,
          show.legend = FALSE) +
  geom_sf(data = mun_limit,
          color = "white",
          fill = NA,
          size = 0.2) +
  bi_scale_fill(pal = "DkViolet",
                dim = 3,
                na.value = "grey90") +
  labs(title = "choropleth",  x = "", y ="") +
  bi_theme() +
  theme(plot.title = element_text(family = "Montserrat", size = 30,
face = "bold")) +
  coord_sf(crs = 4326)
```

Merge both maps

With the help of the `patchwork` package, we combine both maps in a single row, first the choropleth map and on its right the dasymmetric map. More details of the grammar used for the combination of graphics here.

```
# combine
p <- p1 | p2

# final map
p
```