

Introduction to Geological Spatial Data - Peru in R

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Contents

| | |
|--|-----------|
| Making Maps Programming | 1 |
| Data and Basic Plots (<i>coord_sf</i> y <i>geom_sf</i>) | 7 |
| Title, subtitle and axes labels (<i>ggtitle</i> , <i>xlab</i> , <i>ylab</i>) | 8 |
| Color Map (<i>geom_sf</i>) | 8 |
| Projection and Extension (<i>coord_sf</i>) | 10 |
| Arrow and Scale (ggspatial) | 14 |
| Name of City and Others (<i>geom_text</i> , <i>annotate</i>) | 15 |
| Save Map | 16 |
| | |
| Adding Shape of Dots and Polygons: | 16 |
| Dot Data: | 16 |
| Poligonos de Data: | 18 |
| Agregamos labels: | 21 |
| | |
| Multiples Mapas en R: | 22 |
| Conceptos Generales: | 22 |
| Inserción de Mapas: | 30 |
| Comentarios Finales: | 31 |
| | |
| Referencias Bibliográficas: | 31 |

Making Maps Programming

Basic libraries to start:

```
#install.packages(c("cowplot", "googleway", "ggplot2", "ggrepel",
#"ggspatial", "libwgeom", "sf", "rnaturalearth", "rnaturalearthdata"))
```

Preparing information:

```

library("ggplot2")
theme_set(theme_bw()) #best for maps
library("sf")

## Linking to GEOS 3.9.0, GDAL 3.2.1, PROJ 7.2.1

library("plotly")

##
## Attaching package: 'plotly'

## The following object is masked from 'package:ggplot2':
##       last_plot

## The following object is masked from 'package:stats':
##       filter

## The following object is masked from 'package:graphics':
##       layout

library("rnaturalearth") #country world maps
library("rnaturalearthdata") # necesarie to scale = "large"

mundo <- ne_countries(scale = "medium", returnclass = "sf")
# Check some structure
class(mundo)

## [1] "sf"           "data.frame"

str(mundo)

## Classes 'sf' and 'data.frame': 241 obs. of 64 variables:
## $ scalerank : int 3 1 1 1 1 3 3 1 1 1 ...
## $ featurecla: chr "Admin-0 country" "Admin-0 country" "Admin-0 country" "Admin-0 country" ...
## $ labelrank : num 5 3 3 6 6 6 6 4 2 6 ...
## $ sovereign: chr "Netherlands" "Afghanistan" "Angola" "United Kingdom" ...
## $ sov_a3    : chr "NL1" "AFG" "AGO" "GB1" ...
## $ adm0_dif  : num 1 0 0 1 0 1 0 0 0 0 ...
## $ level     : num 2 2 2 2 2 2 2 2 2 2 ...
## $ type      : chr "Country" "Sovereign country" "Sovereign country" "Dependency" ...
## $ admin     : chr "Aruba" "Afghanistan" "Angola" "Anguilla" ...
## $ adm0_a3   : chr "ABW" "AFG" "AGO" "AIA" ...
## $ geou_dif  : num 0 0 0 0 0 0 0 0 0 ...
## $ geounit   : chr "Aruba" "Afghanistan" "Angola" "Anguilla" ...
## $ gu_a3    : chr "ABW" "AFG" "AGO" "AIA" ...
## $ su_dif   : num 0 0 0 0 0 0 0 0 0 ...
## $ subunit   : chr "Aruba" "Afghanistan" "Angola" "Anguilla" ...

```

```

## $ su_a3      : chr "ABW" "AFG" "AGO" "AIA" ...
## $ brk_diff   : num 0 0 0 0 0 0 0 0 ...
## $ name       : chr "Aruba" "Afghanistan" "Angola" "Anguilla" ...
## $ name_long  : chr "Aruba" "Afghanistan" "Angola" "Anguilla" ...
## $ brk_a3     : chr "ABW" "AFG" "AGO" "AIA" ...
## $ brk_name   : chr "Aruba" "Afghanistan" "Angola" "Anguilla" ...
## $ brk_group  : chr NA NA NA NA ...
## $ abbrev     : chr "Aruba" "Afg." "Ang." "Ang." ...
## $ postal    : chr "AW" "AF" "AO" "AI" ...
## $ formal_en : chr "Aruba" "Islamic State of Afghanistan" "People's Republic of Angola" NA ...
## $ formal_fr : chr NA NA NA NA ...
## $ note_adm0 : chr "Neth." NA NA "U.K." ...
## $ note_brk  : chr NA NA NA NA ...
## $ name_sort  : chr "Aruba" "Afghanistan" "Angola" "Anguilla" ...
## $ name_alt   : chr NA NA NA NA ...
## $ mapcolor7  : num 4 5 3 6 1 4 1 2 3 3 ...
## $ mapcolor8  : num 2 6 2 6 4 1 4 1 1 1 ...
## $ mapcolor9  : num 2 8 6 6 1 4 1 3 3 2 ...
## $ mapcolor13 : num 9 7 1 3 6 6 8 3 13 10 ...
## $ pop_est    : num 103065 28400000 12799293 14436 3639453 ...
## $ gdp_md_est: num 2258 22270 110300 109 21810 ...
## $ pop_year   : num NA NA NA NA NA NA NA NA NA ...
## $ lastcensus: num 2010 1979 1970 NA 2001 ...
## $ gdp_year   : num NA NA NA NA NA NA NA NA NA ...
## $ economy    : chr "6. Developing region" "7. Least developed region" "7. Least developed region" "6. Developing region" ...
## $ income_grp : chr "2. High income: nonOECD" "5. Low income" "3. Upper middle income" "3. Upper middle income" ...
## $ wikipedia  : num NA NA NA NA NA NA NA NA NA ...
## $ fips_10    : chr NA NA NA NA ...
## $ iso_a2     : chr "AW" "AF" "AO" "AI" ...
## $ iso_a3     : chr "ABW" "AFG" "AGO" "AIA" ...
## $ iso_n3     : chr "533" "004" "024" "660" ...
## $ un_a3      : chr "533" "004" "024" "660" ...
## $ wb_a2      : chr "AW" "AF" "AO" NA ...
## $ wb_a3      : chr "ABW" "AFG" "AGO" NA ...
## $ woe_id     : num NA NA NA NA NA NA NA NA NA ...
## $ adm0_a3_is : chr "ABW" "AFG" "AGO" "AIA" ...
## $ adm0_a3_us : chr "ABW" "AFG" "AGO" "AIA" ...
## $ adm0_a3_un : num NA NA NA NA NA NA NA NA NA ...
## $ adm0_a3_wb : num NA NA NA NA NA NA NA NA ...
## $ continent  : chr "North America" "Asia" "Africa" "North America" ...
## $ region_un  : chr "Americas" "Asia" "Africa" "Americas" ...
## $ subregion  : chr "Caribbean" "Southern Asia" "Middle Africa" "Caribbean" ...
## $ region_wb  : chr "Latin America & Caribbean" "South Asia" "Sub-Saharan Africa" "Latin America & Caribbean" ...
## $ name_len   : num 5 11 6 8 7 5 7 20 9 7 ...
## $ long_len   : num 5 11 6 8 7 13 7 20 9 7 ...
## $ abbrev_len : num 5 4 4 4 4 5 4 6 4 4 ...
## $ tiny       : num 4 NA NA NA NA 5 5 NA NA NA ...
## $ homepart   : num NA 1 1 NA 1 NA 1 1 1 1 ...
## $ geometry   :sfc_MULTIPOLYGON of length 241; first list element: List of 1
##   ..$ :List of 1
##   ... .$. : num [1:10, 1:2] -69.9 -69.9 -69.9 -70 -70.1 ...
##   ...- attr(*, "class")= chr [1:3] "XY" "MULTIPOLYGON" "sfg"
##   - attr(*, "sf_column")= chr "geometry"
##   - attr(*, "agr")= Factor w/ 3 levels "constant","aggregate",...: NA NA NA NA NA NA NA NA NA ...

```

```

## .. - attr(*, "names")= chr [1:63] "scalerank" "featurecla" "labelrank" "sovereignty" ...
## colnames(mundo)

## [1] "scalerank"   "featurecla"   "labelrank"    "sovereignty"  "sov_a3"
## [6] "adm0_dif"     "level"        "type"        "admin"       "adm0_a3"
## [11] "geou_dif"     "geounit"      "gu_a3"       "su_dif"      "subunit"
## [16] "su_a3"        "brk_diff"     "name"        "name_long"   "brk_a3"
## [21] "brk_name"     "brk_group"    "abbrev"      "postal"      "formal_en"
## [26] "formal_fr"    "note_adm0"    "note_brk"    "name_sort"   "name_alt"
## [31] "mapcolor7"    "mapcolor8"    "mapcolor9"   "mapcolor13"  "pop_est"
## [36] "gdp_md_est"   "pop_year"     "lastcensus"  "gdp_year"   "economy"
## [41] "income_grp"   "wikipedia"   "fips_10"     "iso_a2"     "iso_a3"
## [46] "iso_n3"        "un_a3"        "wb_a2"       "wb_a3"      "woe_id"
## [51] "adm0_a3_is"   "adm0_a3_us"   "adm0_a3_un"  "adm0_a3_wb"  "continent"
## [56] "region_un"    "subregion"   "region_wb"   "name_len"   "long_len"
## [61] "abbrev_len"   "tiny"        "homepart"   "geometry"
head(mundo, 6)

## Simple feature collection with 6 features and 63 fields
## Geometry type: MULTIPOLYGON
## Dimension: XY
## Bounding box: xmin: -70.06611 ymin: -18.01973 xmax: 74.89131 ymax: 60.40581
## CRS: +proj=longlat +datum=WGS84 +no_defs +ellps=WGS84 +towgs84=0,0,0
##   scalerank      featurecla labelrank      sovereignty sov_a3 adm0_dif level
## 0      3 Admin-0 country      5 Netherlands NL1      1      2
## 1      1 Admin-0 country      3 Afghanistan AFG      0      2
## 2      1 Admin-0 country      3      Angola AGO      0      2
## 3      1 Admin-0 country      6 United Kingdom GB1      1      2
## 4      1 Admin-0 country      6      Albania ALB      0      2
## 5      3 Admin-0 country      6      Finland FI1      1      2
##           type      admin adm0_a3 geou_dif      geounit gu_a3 su_dif
## 0      Country      Aruba ABW      0      Aruba ABW      0
## 1 Sovereign country      Afghanistan AFG      0 Afghanistan AFG      0
## 2 Sovereign country      Angola AGO      0      Angola AGO      0
## 3      Dependency      Anguilla AIA      0      Anguilla AIA      0
## 4 Sovereign country      Albania ALB      0      Albania ALB      0
## 5      Country      Aland ALD      0      Aland ALD      0
##           subunit su_a3 brk_diff      name      name_long brk_a3 brk_name
## 0      Aruba ABW      0      Aruba      Aruba ABW      Aruba
## 1 Afghanistan AFG      0 Afghanistan Afghanistan AFG Afghanistan
## 2      Angola AGO      0      Angola      Angola AGO      Angola
## 3      Anguilla AIA      0      Anguilla      Anguilla AIA      Anguilla
## 4      Albania ALB      0      Albania      Albania ALB      Albania
## 5      Aland ALD      0      Aland Islands      Aland ALD      Aland
##           brk_group abbrev postal      formal_en formal_fr note_adm0
## 0      <NA>  Aruba AW      Aruba      <NA>      Neth.
## 1      <NA>  Afg. AF Islamic State of Afghanistan      <NA>      <NA>
## 2      <NA>  Ang. AO People's Republic of Angola      <NA>      <NA>
## 3      <NA>  Ang. AI      <NA>      <NA>      <NA>      U.K.
## 4      <NA>  Alb. AL Republic of Albania      <NA>      <NA>
## 5      <NA>  Aland AI      Aland Islands      <NA>      Fin.

```

```

##   note_brk  name_sort name_alt mapcolor7 mapcolor8 mapcolor9 mapcolor13
## 0      <NA>     Aruba    <NA>        4        2        2        9
## 1      <NA> Afghanistan <NA>        5        6        8        7
## 2      <NA>     Angola    <NA>        3        2        6        1
## 3      <NA>    Anguilla    <NA>        6        6        6        3
## 4      <NA>    Albania    <NA>        1        4        1        6
## 5      <NA>      Aland    <NA>        4        1        4        6
##   pop_est gdp_md_est pop_year lastcensus gdp_year           economy
## 0 103065    2258.0      NA    2010      NA 6. Developing region
## 1 28400000    22270.0      NA    1979      NA 7. Least developed region
## 2 12799293   110300.0      NA    1970      NA 7. Least developed region
## 3 14436      108.9      NA      NA      NA 6. Developing region
## 4 3639453    21810.0      NA    2001      NA 6. Developing region
## 5 27153      1563.0      NA      NA      NA 2. Developed region: nonG7
##           income_grp wikipedia fips_10 iso_a2 iso_a3 iso_n3 un_a3 wb_a2
## 0 2. High income: nonOECD      NA    <NA>    AW    ABW    533    533    AW
## 1          5. Low income      NA    <NA>    AF    AFG    004    004    AF
## 2 3. Upper middle income      NA    <NA>    AO    AGO    024    024    AO
## 3 3. Upper middle income      NA    <NA>    AI    AIA    660    660    <NA>
## 4 4. Lower middle income      NA    <NA>    AL    ALB    008    008    AL
## 5 1. High income: OECD      NA    <NA>    AX    ALA    248    248    <NA>
##   wb_a3 woe_id adm0_a3_is adm0_a3_us adm0_a3_un adm0_a3_wb continent
## 0    ABW     NA      ABW      ABW      NA      NA North America
## 1    AFG     NA      AFG      AFG      NA      NA Asia
## 2    AGO     NA      AGO      AGO      NA      NA Africa
## 3    <NA>    NA      AIA      AIA      NA      NA North America
## 4    ALB     NA      ALB      ALB      NA      NA Europe
## 5    <NA>    NA      ALA      ALD      NA      NA Europe
##   region_un      subregion      region_wb name_len long_len
## 0 Americas      Caribbean Latin America & Caribbean      5      5
## 1 Asia       Southern Asia      South Asia      11      11
## 2 Africa      Middle Africa      Sub-Saharan Africa      6      6
## 3 Americas      Caribbean Latin America & Caribbean      8      8
## 4 Europe      Southern Europe      Europe & Central Asia      7      7
## 5 Europe      Northern Europe      Europe & Central Asia      5     13
##   abbrev_len tiny homepart      geometry
## 0          5    4      NA MULTIPOLYGON ((((-69.89912 1...
## 1          4    NA      1 MULTIPOLYGON (((74.89131 37...
## 2          4    NA      1 MULTIPOLYGON (((14.19082 -5...
## 3          4    NA      NA MULTIPOLYGON ((((-63.00122 1...
## 4          4    NA      1 MULTIPOLYGON (((20.06396 42...
## 5          5    5      NA MULTIPOLYGON (((20.61133 60...

```

```
tail(mundo, 6)
```

```

## Simple feature collection with 6 features and 63 fields
## Geometry type: MULTIPOLYGON
## Dimension: XY
## Bounding box: xmin: -178.1944 ymin: -46.96289 xmax: 54.51113 ymax: 18.99614
## CRS: +proj=longlat +datum=WGS84 +no_defs +ellps=WGS84 +towgs84=0,0,0
##   scalerank      featurecla labelrank  sovereignt sov_a3 adm0_dif level
## 235          3 Admin-0 country      4      France    FR1      1      2
## 236          1 Admin-0 country      4      Samoa     WSM      0      2
## 237          1 Admin-0 country      3      Yemen     YEM      0      2

```

```

## 238      1 Admin-0 country          2 South Africa    ZAF      0      2
## 239      1 Admin-0 country          3     Zambia     ZMB      0      2
## 240      1 Admin-0 country          3   Zimbabwe    ZWE      0      2
##           type      admin adm0_a3 geou_dif      geounit
## 235      Dependency Wallis and Futuna    WLF      0 Wallis and Futuna
## 236 Sovereign country            Samoa    WSM      0        Samoa
## 237 Sovereign country            Yemen    YEM      0        Yemen
## 238 Sovereign country          South Africa    ZAF      0 South Africa
## 239 Sovereign country            Zambia   ZMB      0        Zambia
## 240 Sovereign country          Zimbabwe    ZWE      0        Zimbabwe
##           gu_a3 su_dif      subunit su_a3 brk_diff      name
## 235      WLF      0 Wallis and Futuna    WLF      0 Wallis and Futuna Is.
## 236      WSM      0        Samoa    WSM      0        Samoa
## 237      YEM      0        Yemen    YEM      0        Yemen
## 238      ZAF      0 South Africa    ZAF      0 South Africa
## 239      ZMB      0        Zambia   ZMB      0        Zambia
## 240      ZWE      0   Zimbabwe    ZWE      0        Zimbabwe
##           name_long brk_a3      brk_name brk_group abbrev
## 235 Wallis and Futuna Islands    WLF Wallis and Futuna Islands <NA> Wlf.
## 236            Samoa    WSM            Samoa <NA> Samoa
## 237            Yemen    YEM            Yemen <NA> Yem.
## 238          South Africa    ZAF          South Africa <NA> S.Af.
## 239            Zambia   ZMB            Zambia <NA> Zambia
## 240            Zimbabwe    ZWE            Zimbabwe <NA> Zimb.
##           postal      formal_en formal_fr note_adm0 note_brk
## 235      WF Wallis and Futuna Islands <NA>      Fr. <NA>
## 236      WS Independent State of Samoa <NA> <NA> <NA>
## 237      YE Republic of Yemen <NA> <NA> <NA>
## 238      ZA Republic of South Africa <NA> <NA> <NA>
## 239      ZM Republic of Zambia <NA> <NA> <NA>
## 240      ZW Republic of Zimbabwe <NA> <NA> <NA>
##           name_sort name_alt mapcolor7 mapcolor8 mapcolor9 mapcolor13
## 235 Wallis and Futuna <NA>      7      5      9      11
## 236            Samoa <NA>      3      3      4       6
## 237      Yemen, Rep. <NA>      5      3      3      11
## 238          South Africa <NA>      2      3      4       2
## 239            Zambia <NA>      5      8      5      13
## 240            Zimbabwe <NA>      1      5      3       9
##           pop_est gdp_md_est pop_year lastcensus gdp_year      economy
## 235      15289       60      NA      NA      NA 6. Developing region
## 236      219998      1049      NA      2006      NA 7. Least developed region
## 237 23822783      55280      NA      2004      NA 7. Least developed region
## 238 49052489      491000      NA      2001      NA 5. Emerging region: G20
## 239 11862740      17500      NA      2010      NA 7. Least developed region
## 240 12619600      9323       0      2002       0 5. Emerging region: G20
##           income_grp wikipedia fips_10 iso_a2 iso_a3 iso_n3 un_a3 wb_a2
## 235 4. Lower middle income      NA <NA> WF  WLF  876  876 <NA>
## 236 4. Lower middle income      NA <NA> WS  WSM  882  882 WS
## 237 4. Lower middle income      NA <NA> YE  YEM  887  887 RY
## 238 3. Upper middle income      NA <NA> ZA  ZAF  710  710 ZA
## 239 4. Lower middle income      NA <NA> ZM  ZMB  894  894 ZM
## 240      5. Low income         NA <NA> ZW  ZWE  716  716 ZW
##           wb_a3 woe_id adm0_a3_is adm0_a3_us adm0_a3_un adm0_a3_wb continent
## 235 <NA>      NA      WLF      WLF      NA      NA Oceania

```

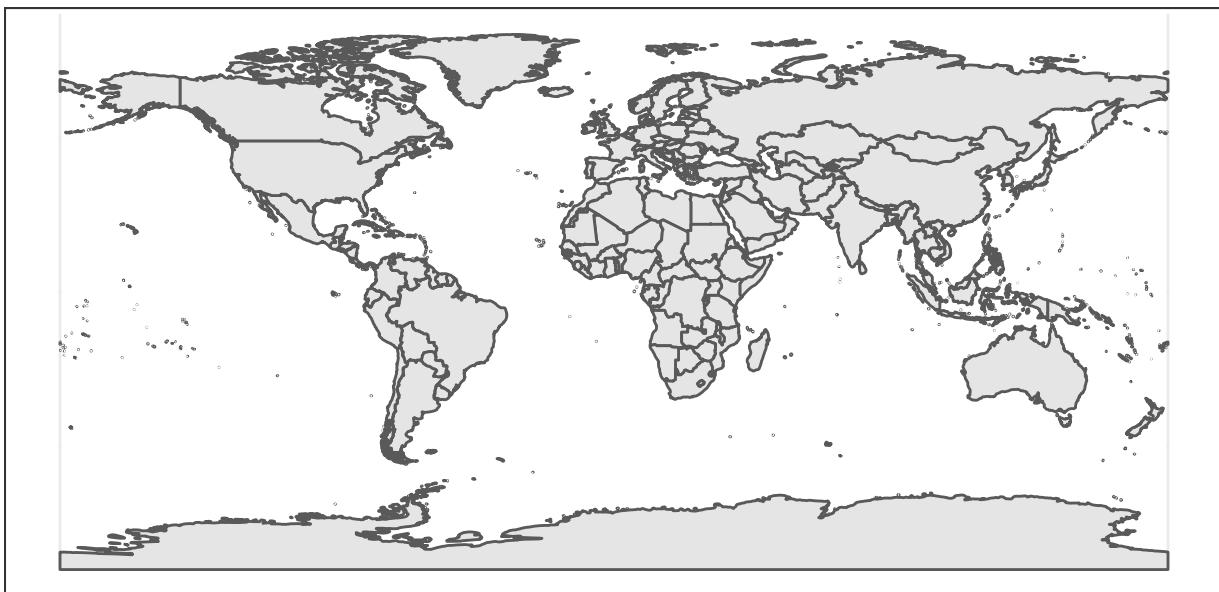
```

## 236   WSM    NA      WSM    WSM    NA      NA   Oceania
## 237   YEM    NA      YEM    YEM    NA      NA   Asia
## 238   ZAF    NA      ZAF    ZAF    NA      NA   Africa
## 239   ZMB    NA      ZMB    ZMB    NA      NA   Africa
## 240   ZWE    NA      ZWE    ZWE    NA      NA   Africa
##       region_un    subregion      region_wb name_len long_len
## 235   Oceania    Polynesia    East Asia & Pacific 21      25
## 236   Oceania    Polynesia    East Asia & Pacific 5       5
## 237   Asia      Western Asia Middle East & North Africa 5      5
## 238   Africa     Southern Africa Sub-Saharan Africa 12      12
## 239   Africa     Eastern Africa Sub-Saharan Africa 6       6
## 240   Africa     Eastern Africa Sub-Saharan Africa 8       8
##       abbrev_len tiny homepart      geometry
## 235       4     3    NA MULTIPOLYGON (((-178.0467 -...
## 236       5     NA   1 MULTIPOLYGON (((-171.4541 -...
## 237       4     NA   1 MULTIPOLYGON (((53.76318 12...
## 238       5     NA   1 MULTIPOLYGON (((37.85693 -4...
## 239       6     NA   1 MULTIPOLYGON (((32.91992 -9...
## 240       5     NA   1 MULTIPOLYGON (((31.28789 -2...

```

Data and Basic Plots (*coord_sf* y *geom_sf*)

```
ggplot(data = mundo)+  
  geom_sf()
```

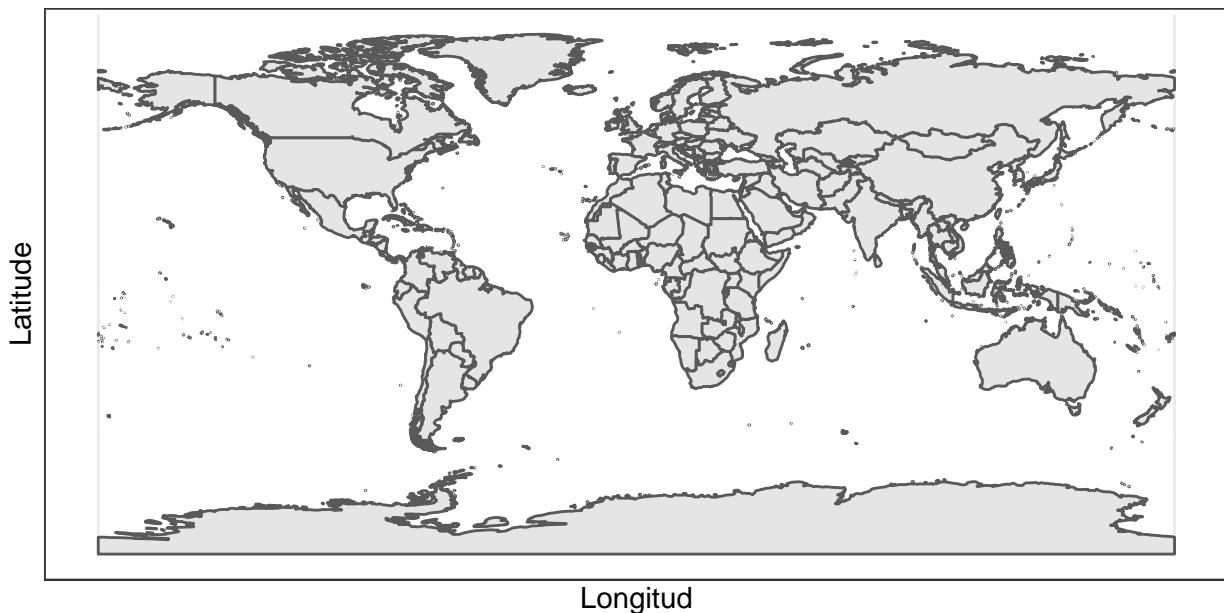


Title, subtitle and axes labels (*ggtitle*, *xlab*, *ylab*)

```
ggplot(data = mundo)+  
  geom_sf() +  
  xlab("Longitud") + ylab("Latitude") +  
  ggtitle("World Maps", subtitle = paste0("(", length(unique(mundo$name)), "country)"))
```

World Maps

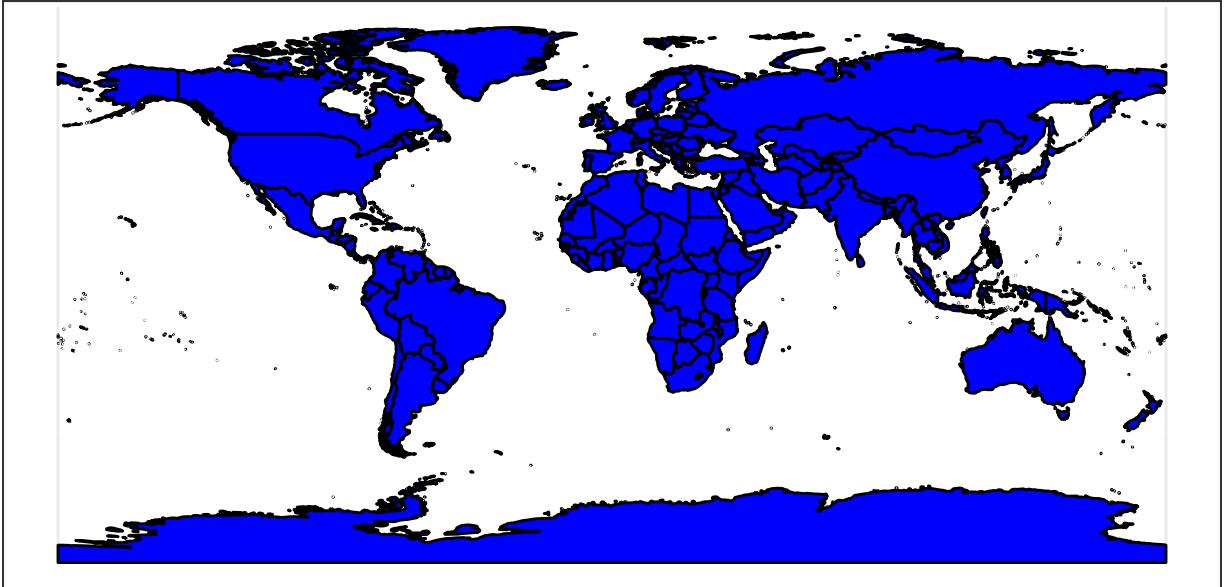
(241country)



Color Map (*geom_sf*)

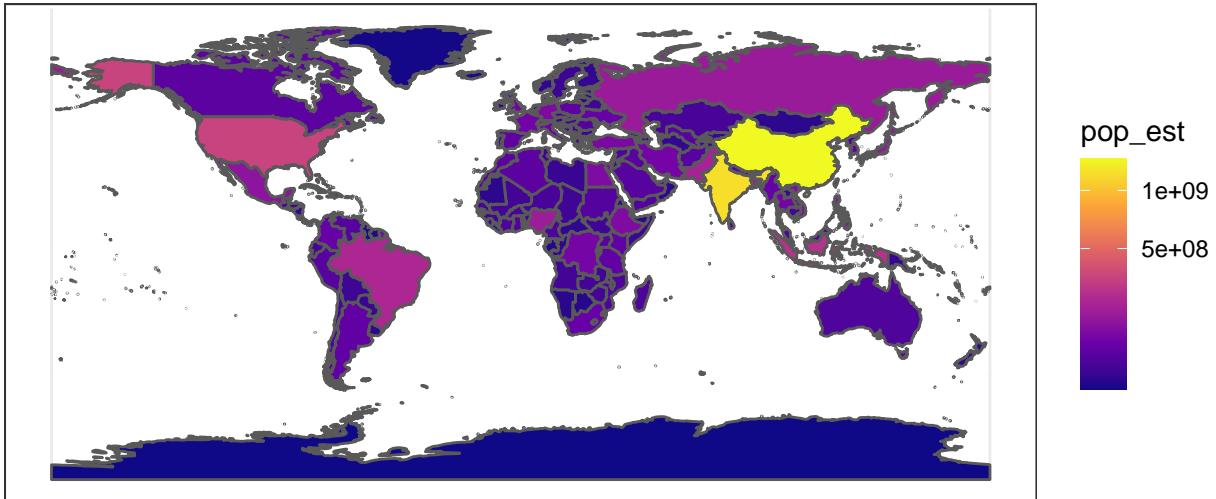
A first simple map:

```
ggplot(data = mundo)+  
  geom_sf(color = "black", fill = "blue")
```



Generating a best map:

```
a <- ggplot(data = mundo) +  
  geom_sf(aes(fill = pop_est)) +  
  scale_fill_viridis_c(option = "plasma", trans = "sqrt")  
a
```



Projection and Extension (*coord_sf*)

coord_sf allow work with coordinate system including both projections and extensions of map. The argument **crs** is possible overwrite the configuration and project wherever. This can be use with all kind of validation of **PROJ4 string**.

```
ggplot(data = mundo) +  
  geom_sf() +  
  coord_sf(crs = "+proj=laea +lat_0=52 +lon_0=10 +x_0=4321000 +y_0=3210000 +ellps=GRS80 +units=m +no_c
```



If we want to use Spatial Reference System Identifier (SRID) or European Petroleum Survey Group (EPSG) code available for Peru:

```
ggplot(data = mundo) +  
  geom_sf() +  
  coord_sf(crs = "+init=epsg:3035")
```



```
ggplot(data = mundo) +  
  geom_sf() +  
  coord_sf(crs = st_crs(3035))
```



We generate zoom in Peru to add the map of **South America**. *Let's go (Vamos)!*

```
ggplot(data = mundo) +  
  geom_sf() +  
  coord_sf(xlim = c(-90.00, -30.5), ylim = c(-57.00, 14.00), expand = FALSE)
```

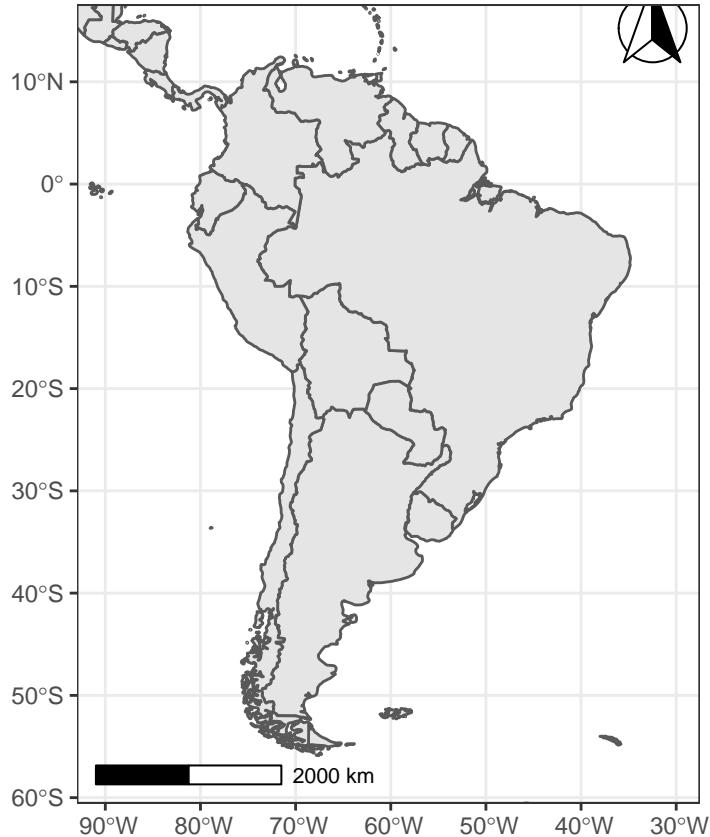


Arrow and Scale (ggspatial)

Exist a variety of packages like `prettymapr`, `vsd`, `ggsn`, `legendMap`. We are going to use `ggspatial`.

```
library(ggspatial)

ggplot(data = mundo) +
  geom_sf() +
  annotation_scale(location = "bl", width_hint = 0.4) +
  annotation_north_arrow(location = "bl", which_north = "true",
    pad_x = unit(2.70, "in"), pad_y = unit(3.80, "in"),
    style = north_arrow_fancy_orienteering) +
  coord_sf(xlim = c(-90.00, -30.5), ylim = c(-57.00, 14.00))
```



```
## Scale on map varies by more than 10%, scale bar may be inaccurate
```

Name of City and Others (*geom_text, annotate*)

We can use like we see at the beginning of the data **world** how to regularize a *data.frame* in ggplot2.

```
library("sf")
sf_use_s2(FALSE)

## Spherical geometry (s2) switched off

world_points<- st_centroid(mundo)
world_points <- cbind(mundo, st_coordinates(st_centroid(mundo$geometry)))

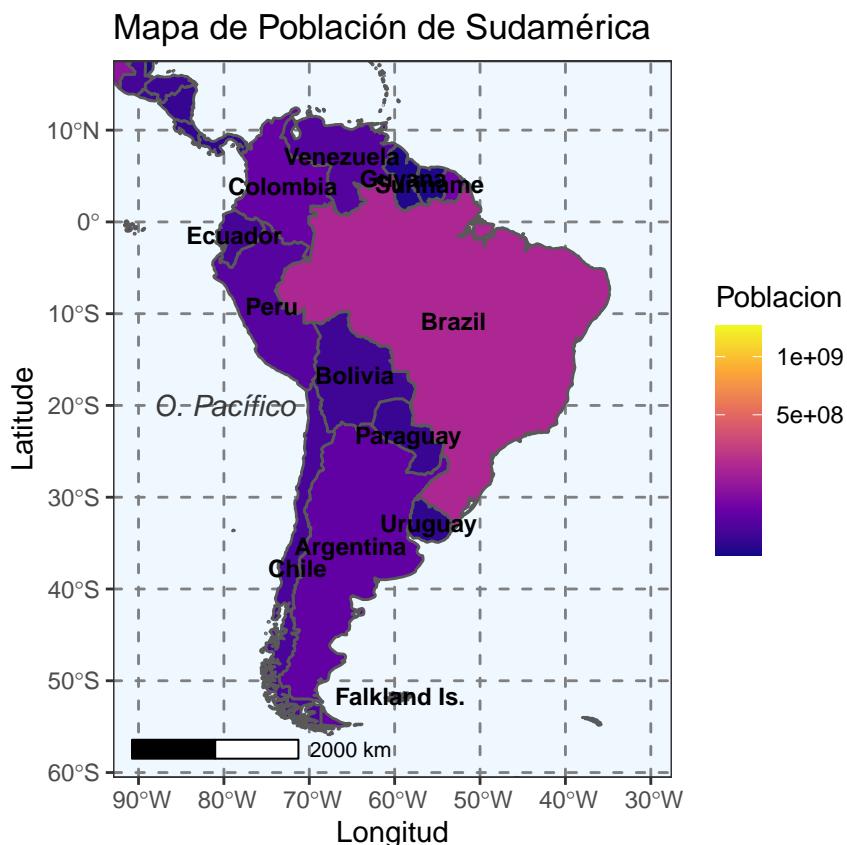
mundo <- mundo %>%
  dplyr::rename(Poblacion = pop_est)

ggplot(data = mundo) +
  geom_sf(aes(fill = Poblacion)) +
  scale_fill_viridis_c(option = "plasma", trans = "sqrt")+
  geom_text(data= world_points[world_points$continent=="South America", ],aes(x=X, y=Y, label=name),
            color = "black", fontface = "bold", check_overlap = FALSE, size = 3) +
  annotate(geom = "text", x = -80, y = -20, label = "O. Pacífico",
```

```

    fontface = "italic", color = "grey22", size = 4) +
annotation_scale(location = "bl", width_hint = 0.4) +
annotation_north_arrow(location = "bl", which_north = "true",
  pad_x = unit(2.65, "in"), pad_y = unit(3.70, "in"),
  style = north_arrow_fancy_orienteering) +
coord_sf(xlim = c(-90.00, -30.5), ylim = c(-57.00, 14.00))+
xlab("Longitud") + ylab("Latitude") +
ggtitle("Mapa de Población de Sudamérica") +
theme(panel.grid.major = element_line(color = gray(.5), linetype = "dashed", size = 0.5), panel.backg

```



Save Map

```

ggsave("map.pdf")
ggsave("map_web.png", width = 6, height = 6, dpi = "screen")

```

Adding Shape of Dots and Polygons:

Dot Data:

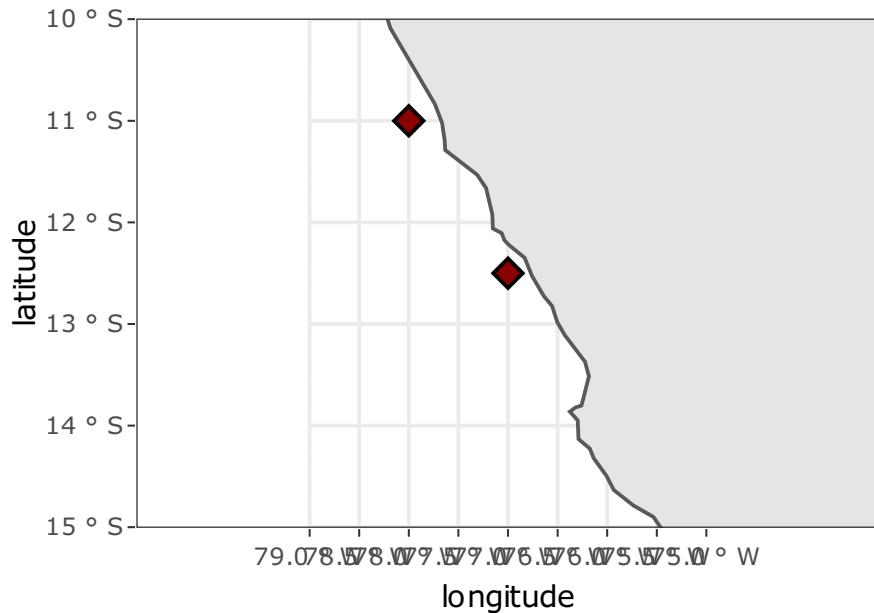
Creamos puntos de Data entre la Isla San Lorenzo y Lima:

```
(sites <- data.frame(longitude = c(-78, -77), latitude = c(-11,
-12.5)))
```

```
##   longitude latitude
## 1      -78     -11.0
## 2      -77     -12.5
```

- Plotemos esas coordenadas (forma rápida):

```
m <- ggplot(data = mundo) +
  geom_sf() +
  geom_point(data = sites, aes(x = longitude, y = latitude), size = 3,
             shape = 23, fill = "darkred") +
  coord_sf(xlim = c(-79, -75), ylim = c(-10, -15), expand = FALSE)
ggplotly(m)
```



- Forma adecuada:

Una alternativa mejor y más flexible es *usar el poder de sf*: convertir el marco de datos en un objeto sf permite confiar en sf para manejar sobre la marcha el sistema de coordenadas (proyección y extensión), lo cual puede ser muy útil si los dos los objetos (aquí mapa del mundo y sitios) no están en la misma proyección. Para lograr el mismo resultado, la proyección (aquí WGS84, que es el código CRS #4326) tiene que estar definida a priori en el objeto sf:

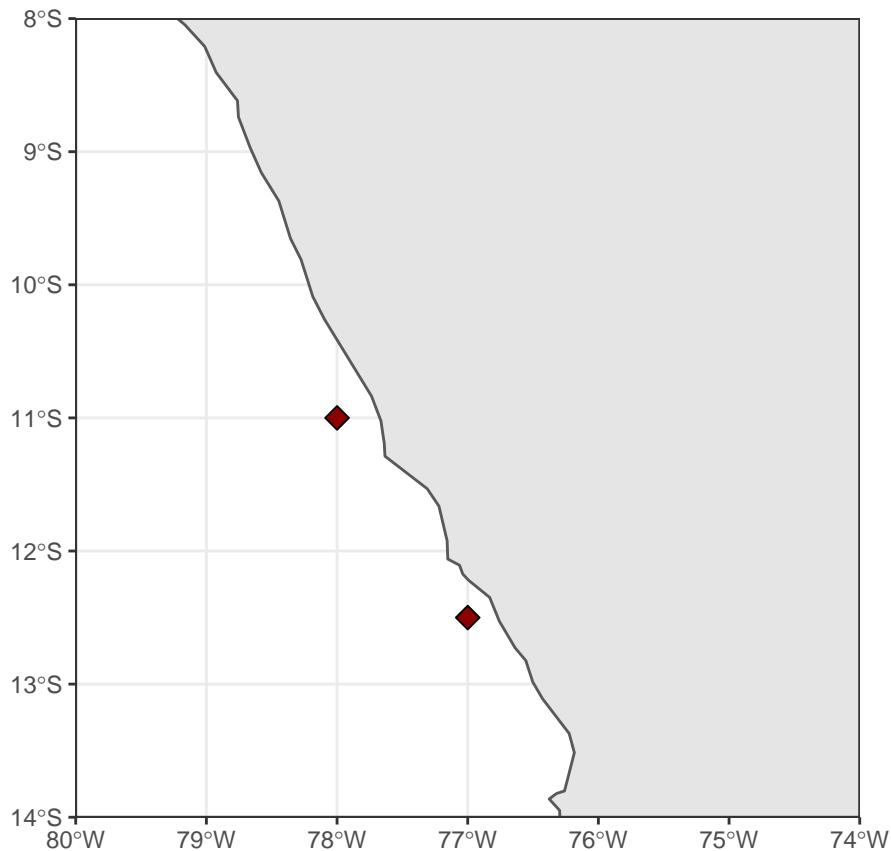
```

(sites <- st_as_sf(sites, coords = c("longitude", "latitude"),
  crs = 4326, agr = "constant"))

## Simple feature collection with 2 features and 0 fields
## Geometry type: POINT
## Dimension:      XY
## Bounding box:  xmin: -78 ymin: -12.5 xmax: -77 ymax: -11
## Geodetic CRS:  WGS 84
##               geometry
## 1   POINT (-78 -11)
## 2 POINT (-77 -12.5)

ggplot(data = mundo) +
  geom_sf() +
  geom_sf(data = sites, size = 3, shape = 23, fill = "darkred") +
  coord_sf(xlim = c(-80, -74), ylim = c(-8, -14), expand = FALSE)

```



Poligonos de Data:

```

Departamento <- st_read(
  "data_peru/DEPARTAMENTOS.shp")

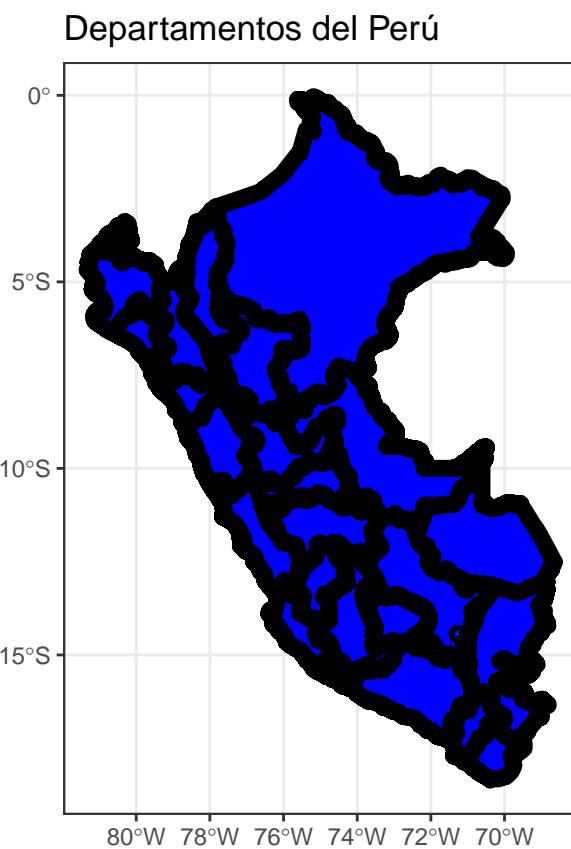
```

```

## Reading layer 'DEPARTAMENTOS' from data source
##   'D:\1.2Autonomo_AI\1er_entregable\Geospatial_Introduction\data_peru\DEPARTAMENTOS.shp'
##   using driver 'ESRI Shapefile'
## Simple feature collection with 25 features and 4 fields
## Geometry type: MULTIPOLYGON
## Dimension:       XY
## Bounding box:   xmin: -81.32823 ymin: -18.35093 xmax: -68.65228 ymax: -0.03860597
## Geodetic CRS:   WGS 84

ggplot() +
  geom_sf(data = Departamento, size = 3, color = "black", fill = "blue" ) +
  ggtitle("Departamentos del Perú") +
  coord_sf()

```



```
Provincias <- st_read("data_peru/PROVINCIAS.shp")
```

```

## Reading layer 'PROVINCIAS' from data source
##   'D:\1.2Autonomo_AI\1er_entregable\Geospatial_Introduction\data_peru\PROVINCIAS.shp'
##   using driver 'ESRI Shapefile'
## Simple feature collection with 196 features and 7 fields
## Geometry type: MULTIPOLYGON
## Dimension:       XY
## Bounding box:   xmin: -81.32823 ymin: -18.35093 xmax: -68.65228 ymax: -0.03860597
## Geodetic CRS:   WGS 84

```

```

Departamentos <- Provincias %>% group_by(DEPARTAMEN) %>%
  dplyr::summarise(
    tot_area = sum(Area),
    ID = unique(IDDPTO)
  )
head(Departamentos)

## Simple feature collection with 6 features and 3 fields
## Geometry type: POLYGON
## Dimension: XY
## Bounding box: xmin: -79.45845 ymin: -17.28501 xmax: -70.80408 ymax: -2.986125
## Geodetic CRS: WGS 84
## # A tibble: 6 x 4
##   DEPARTAMEN tot_area ID
##   <chr>      <dbl> <chr>          geometry
## 1 AMAZONAS     39356. 01  ((-78.63847 -4.493235, -78.63815 -4.491043, -78.637~
## 2 ANCASH       35940. 02  ((-78.22723 -9.794615, -78.2273 -9.794449, -78.2277~
## 3 APURIMAC     21114. 03  ((-73.6748 -13.72874, -73.67533 -13.72828, -73.6770~
## 4 AREQUIPA     63256. 04  ((-73.29186 -16.40425, -73.29167 -16.40406, -73.291~
## 5 AYACUCHO      43509. 05  ((-74.78295 -13.57767, -74.78304 -13.57761, -74.783~
## 6 CAJAMARCA    32949. 06  ((-79.24974 -6.22143, -79.2504 -6.2209, -79.25142 --

sf_use_s2(FALSE)
Departamentos <- cbind(Departamentos, st_coordinates(st_centroid(Departamentos)))
Provincias <- cbind(Provincias, st_coordinates(st_centroid(Provincias)))
library("tools")
Departamentos$DEPARTAMEN <- toTitleCase(Departamentos$DEPARTAMEN)
head(Departamentos)

## Simple feature collection with 6 features and 5 fields
## Geometry type: POLYGON
## Dimension: XY
## Bounding box: xmin: -79.45845 ymin: -17.28501 xmax: -70.80408 ymax: -2.986125
## Geodetic CRS: WGS 84
##   DEPARTAMEN tot_area ID      X          Y          geometry
## 1 AMAZONAS     39355.85 01 -78.05489 -5.070729 POLYGON ((-78.63847 -4.4932...
## 2 ANCASH       35940.08 02 -77.66997 -9.407022 POLYGON ((-78.22723 -9.7946...
## 3 APURIMAC     21114.15 03 -72.97538 -14.028136 POLYGON ((-73.6748 -13.7287...
## 4 AREQUIPA     63255.89 04 -72.47623 -15.842924 POLYGON ((-73.29186 -16.404...
## 5 AYACUCHO      43508.58 05 -74.08367 -14.088610 POLYGON ((-74.78295 -13.577...
## 6 CAJAMARCA    32948.76 06 -78.74544 -6.433003 POLYGON ((-79.24974 -6.2214...

t <- ggplot(data = mundo) +
  geom_sf(fill = "gray90") +
  geom_sf(data = sites, size = 5, shape = 23, fill = "darkred")+
  geom_sf(data = Departamentos, fill = Departamentos$tot_area) +
  scale_fill_viridis_c(option = "plasma") +
  geom_text(data = Departamentos, aes(X, Y, label = DEPARTAMEN), size = 3) +
  annotation_scale(location = "bl", width_hint = 0.4) +
  annotation_north_arrow(location = "bl", which_north = "true",
    pad_x = unit(0.50, "in"), pad_y = unit(0.40, "in"),
    style = north_arrow_nautical)+
```

```

coord_sf(xlim = c(-80, -74), ylim = c(-10, -14), expand = FALSE) +
xlab("Longitud") + ylab("Latitud") +
ggtitle("Análisis Geoespacial", subtitle = "(Departamento Lima)") +
theme(panel.grid.major = element_line(color = gray(0.5), linetype = "dashed",
size = 0.5), panel.background = element_rect(fill = "aliceblue"))

db_ciudades <- read.csv(file="data_peru/pe.csv", header = TRUE)
cols <- c("Lima", "Cerro de Pasco", "Junin", "Huancavelica")
db_ciudad <- db_ciudades[db_ciudades$city %in% cols, ]

(flcities <- st_as_sf(db_ciudad, coords = c("lng", "lat"), remove = FALSE,
crs = 4326, agr = "constant"))

## Simple feature collection with 4 features and 9 fields
## Attribute-geometry relationship: 9 constant, 0 aggregate, 0 identity
## Geometry type: POINT
## Dimension: XY
## Bounding box: xmin: -77.0333 ymin: -12.785 xmax: -74.9714 ymax: -10.6864
## Geodetic CRS: WGS 84
##           city      lat      lng country iso2 admin_name capital
## 1         Lima -12.0500 -77.0333 Peru   PE      Lima primary
## 39 Cerro de Pasco -10.6864 -76.2625 Peru   PE      Pasco admin
## 46 Huancavelica -12.7850 -74.9714 Peru   PE Huancavelica admin
## 81 Junin -11.1500 -75.9833 Peru   PE      Junin
##   population population_proper      geometry
## 1     9848000          8894000  POINT (-77.0333 -12.05)
## 39     58899          58899  POINT (-76.2625 -10.6864)
## 46     49570          49570  POINT (-74.9714 -12.785)
## 81     15320          7670  POINT (-75.9833 -11.15)

```

Agregamos labels:

```

library(ggrepel)
tt <- ggplot(data = mundo) +
geom_sf(fill = "antiquewhite1") +
geom_sf(data = Departamentos) +
geom_sf(data = Provincias[Provincias$DEPARTAMEN=="LIMA", ],
aes(fill = Provincias[Provincias$DEPARTAMEN=="LIMA", ]$Area))++
guides(fill=guide_legend(title="Area(km^2)"))+
scale_fill_viridis_c(option = "plasma")+
geom_sf(data = sites, size = 5, shape = 23, fill = "darkred")+
coord_sf(xlim = c(-80, -74), ylim = c(-10, -14), expand = FALSE) +
geom_sf(data = flcities) +
geom_text_repel(data = flcities, aes(x = lng, y = lat, label = city),
fontface = "bold", nudge_x = c(0.2, 0.5, 0.6, 0.6), nudge_y = c(0.25,
0.25, 0.25, -0.25)) +
geom_label(data = Provincias[Provincias$DEPARTAMEN=="LIMA", ],
aes(X, Y, label = CAPITAL), size = 2) +
annotation_scale(location = "bl", width_hint = 0.4) +
annotation_north_arrow(location = "bl", which_north = "true",
pad_x = unit(0.50, "in"), pad_y = unit(0.40, "in"))

```

```

    style = north_arrow_nautical)+  

  coord_sf(xlim = c(-80, -74), ylim = c(-10, -14), expand = FALSE)+  

  xlab("Longitud") + ylab("Latitud") +  

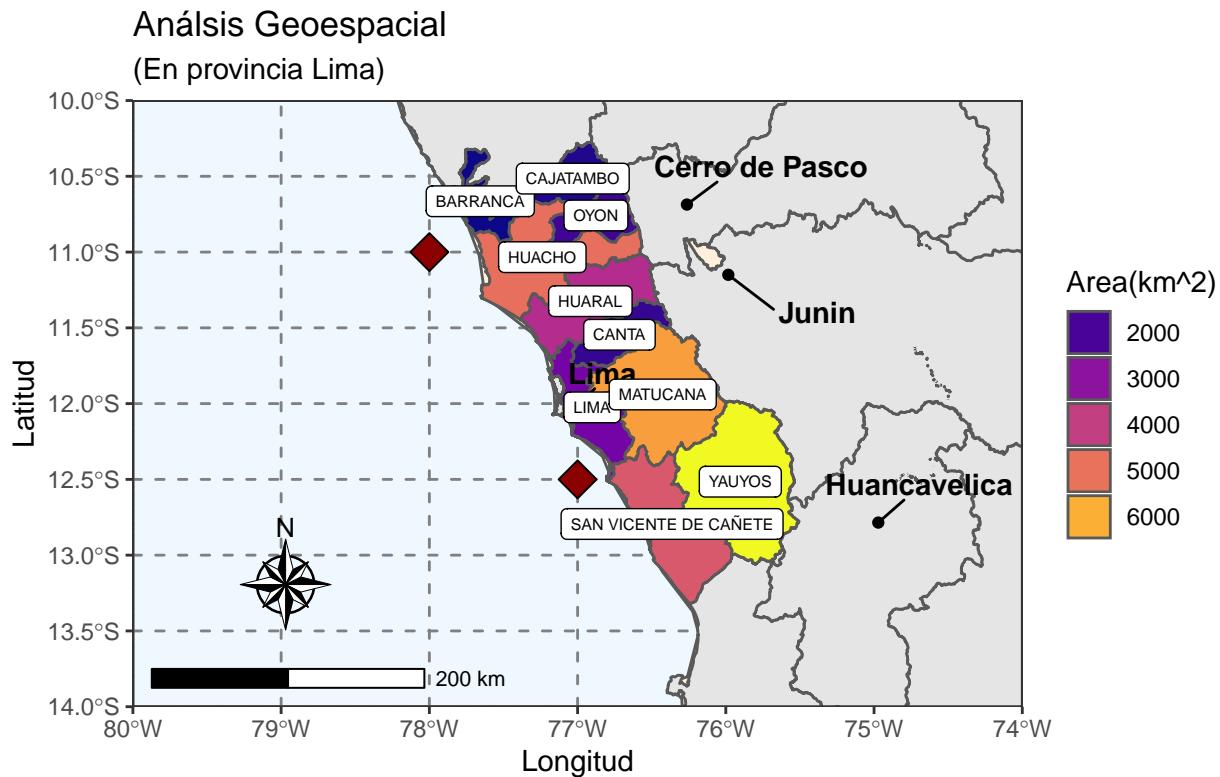
  ggttitle("Análisis Geoespacial", subtitle = "(En provincia Lima)") +  

  theme(panel.grid.major = element_line(color = gray(0.5), linetype = "dashed",  

    size = 0.5), panel.background = element_rect(fill = "aliceblue"))

```

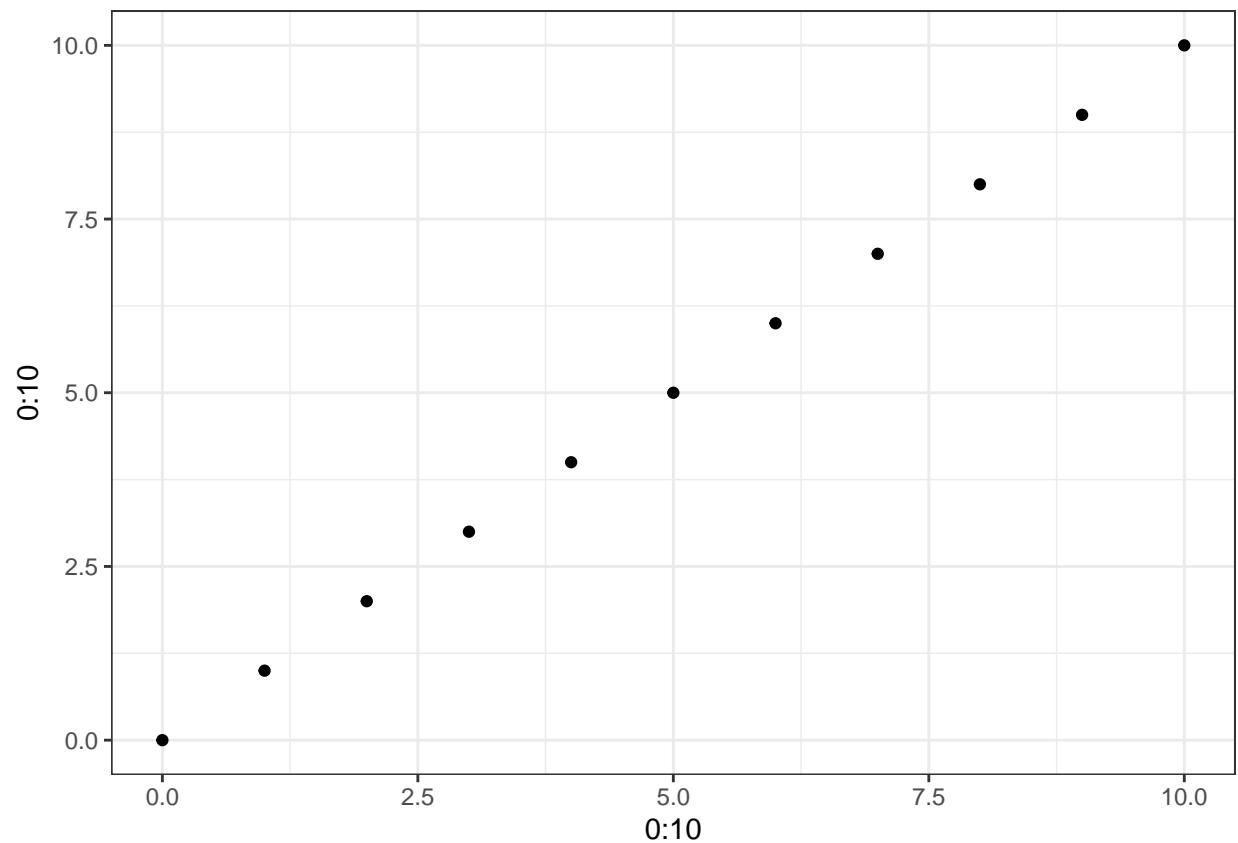
tt



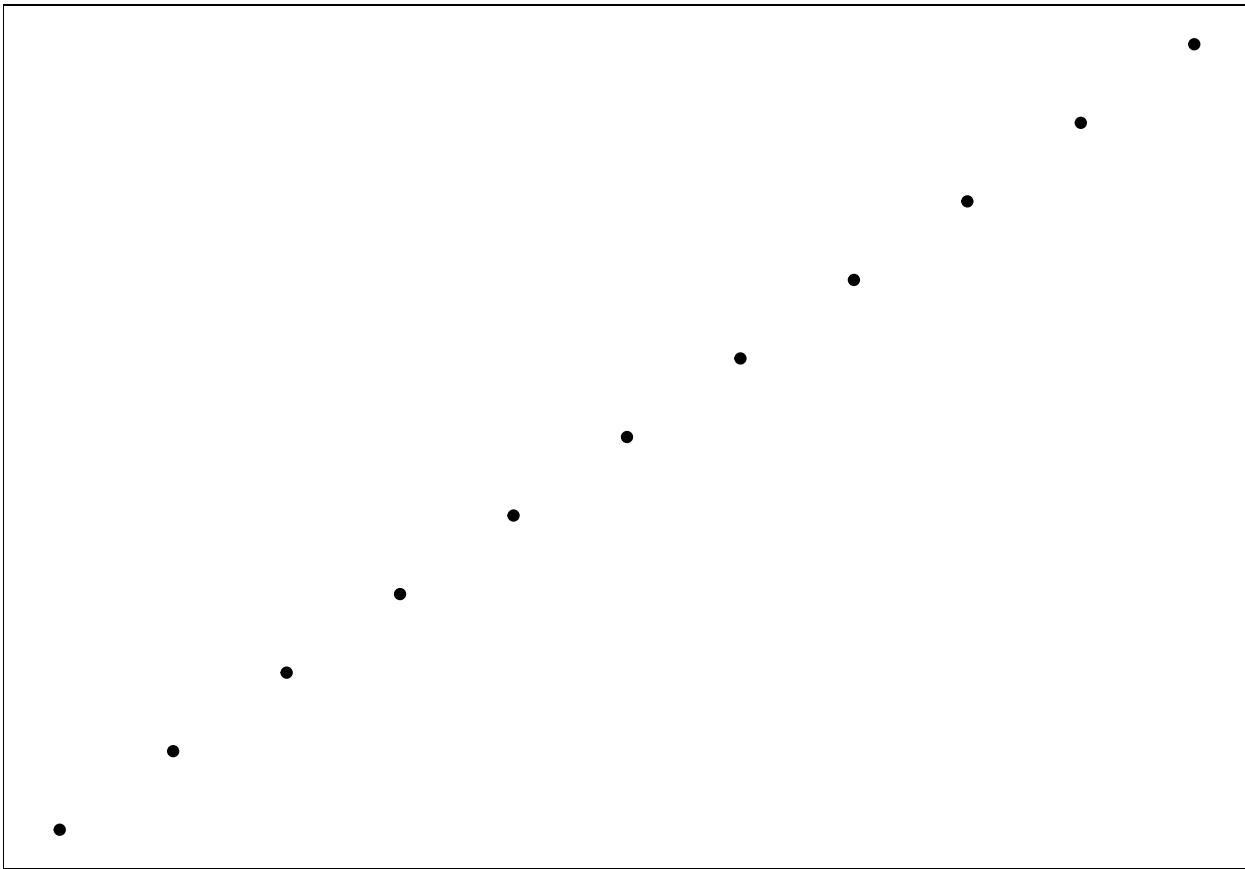
Multiples Mapas en R:

Conceptos Generales:

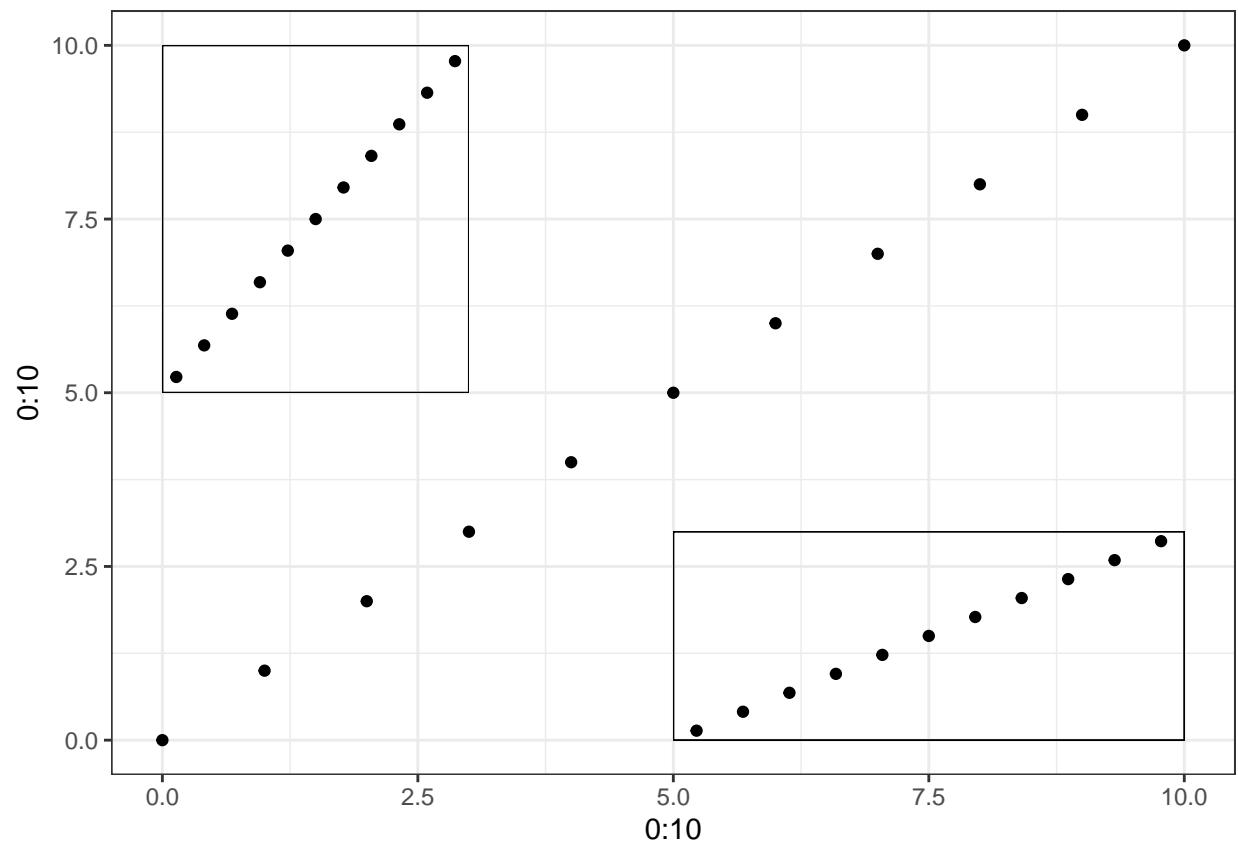
```
(g1 <- qplot(0:10, 0:10))
```



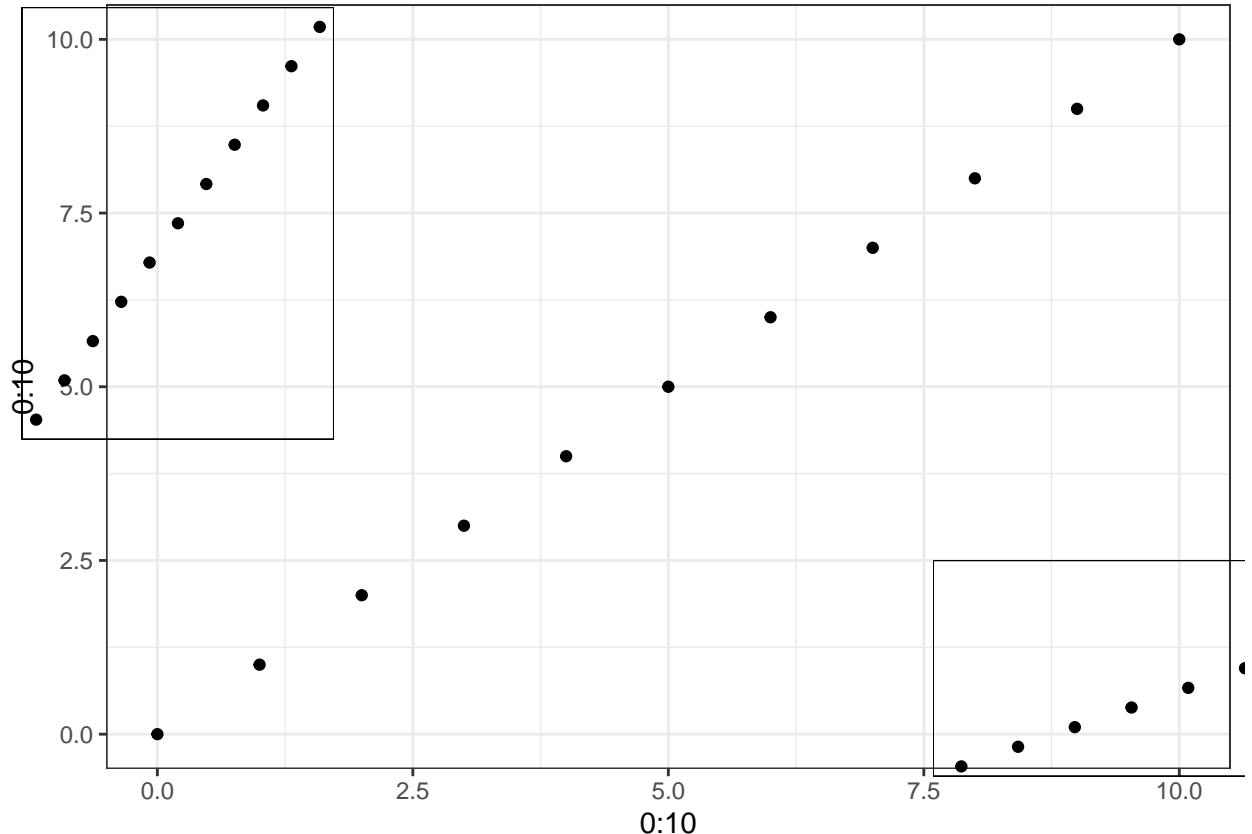
```
(g1_void <- g1 + theme_void() + theme(panel.border = element_rect(colour = "black",
  fill = NA)))
```



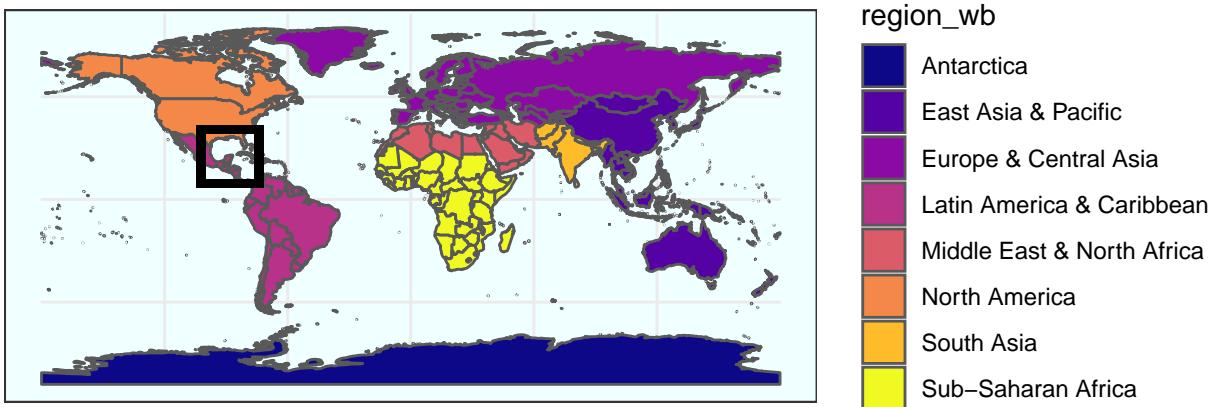
```
g1 +
  annotation_custom(
    grob = ggplotGrob(g1_void),
    xmin = 0,
    xmax = 3,
    ymin = 5,
    ymax = 10
  ) +
  annotation_custom(
    grob = ggplotGrob(g1_void),
    xmin = 5,
    xmax = 10,
    ymin = 0,
    ymax = 3
  )
```



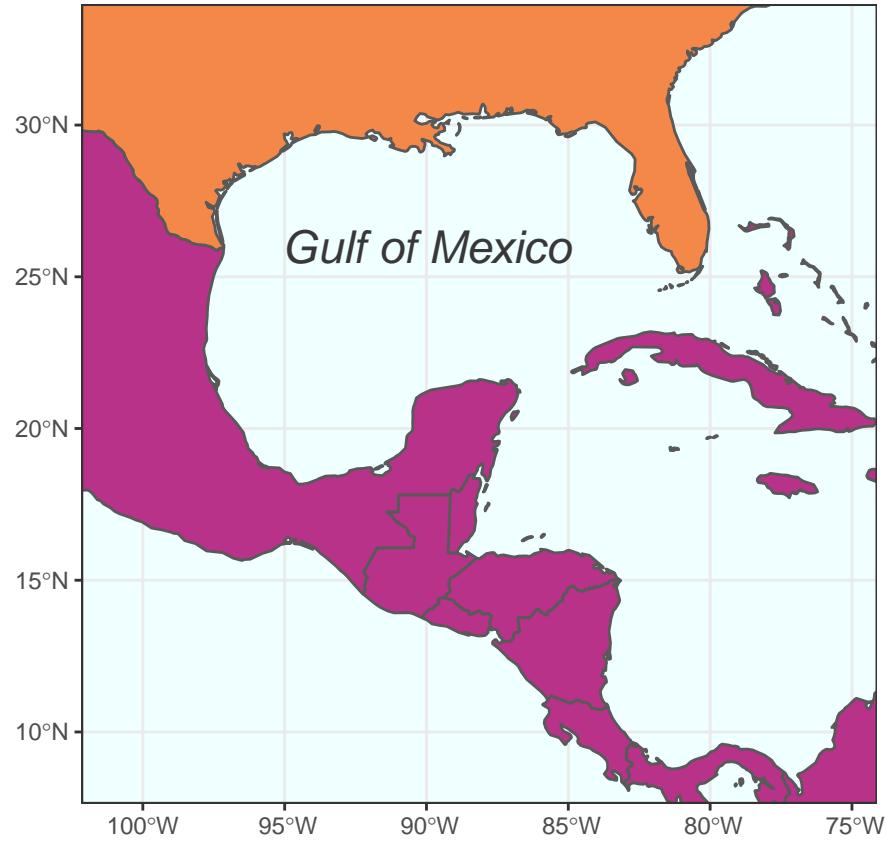
```
library(cowplot)
ggdraw(g1) + draw_plot(g1_void, width = 0.25, height = 0.5, x = 0.02, y = 0.48) + draw_plot(g1_void, wi
```



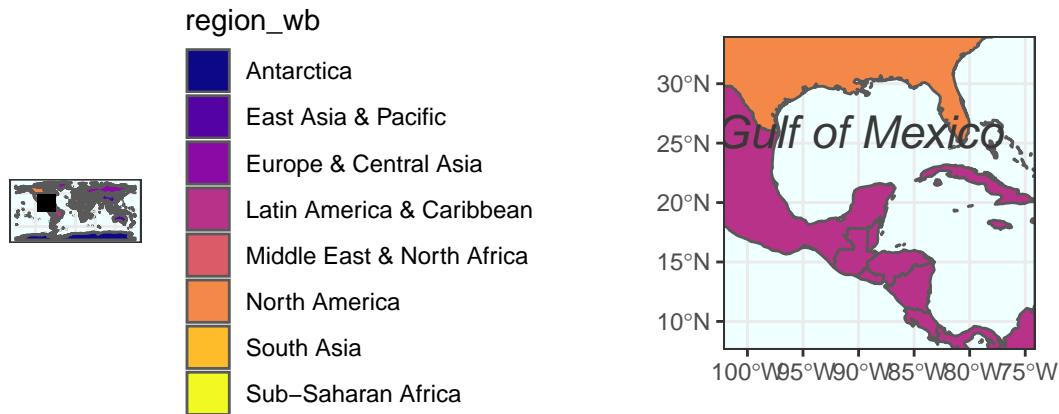
```
(gworld <- ggplot(data = mundo) +
  geom_sf(aes(fill = region_wb)) +
  geom_rect(xmin = -102.15, xmax = -74.12, ymin = 7.65, ymax = 33.97,
            fill = NA, colour = "black", size = 1.5) +
  scale_fill_viridis_d(option = "plasma") +
  theme(panel.background = element_rect(fill = "azure"),
        panel.border = element_rect(fill = NA)))
```



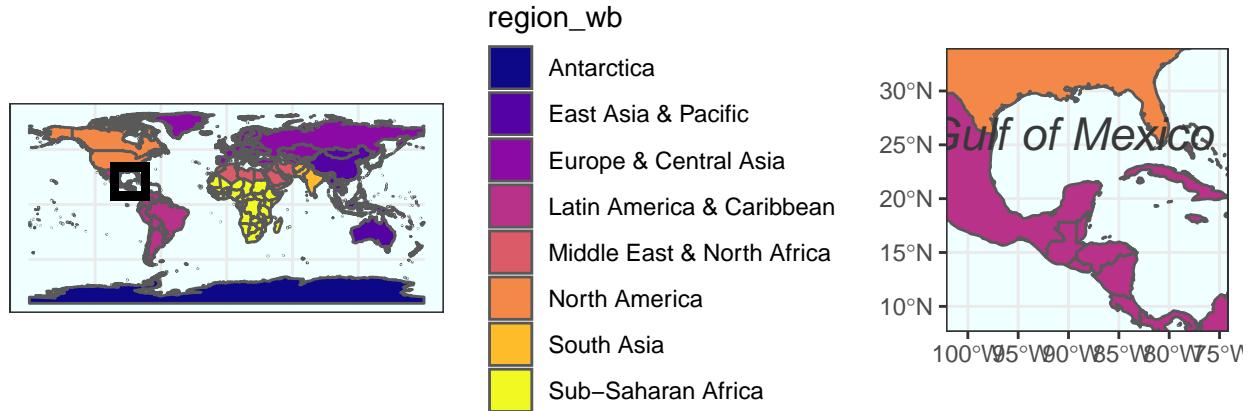
```
(ggulf <- ggplot(data = mundo) +
  geom_sf(aes(fill = region_wb)) +
  annotate(geom = "text", x = -90, y = 26, label = "Gulf of Mexico",
    fontface = "italic", color = "grey22", size = 6) +
  coord_sf(xlim = c(-102.15, -74.12), ylim = c(7.65, 33.97), expand = FALSE) +
  scale_fill_viridis_d(option = "plasma") +
  theme(legend.position = "none", axis.title.x = element_blank(),
    axis.title.y = element_blank(), panel.background = element_rect(fill = "azure"),
    panel.border = element_rect(fill = NA)))
```



```
ggplot() +  
  coord_equal(xlim = c(0, 3.3), ylim = c(0, 1), expand = FALSE) +  
  annotation_custom(ggplotGrob(gworld), xmin = 0, xmax = 1.5, ymin = 0,  
                    ymax = 1) +  
  annotation_custom(ggplotGrob(ggulf), xmin = 1.5, xmax = 3, ymin = 0,  
                    ymax = 1) +  
  theme_void()
```



```
plot_grid(gworld, ggulf, nrow = 1, rel_widths = c(2.3, 1))
```



```
ggsave("grid.pdf", width = 15, height = 5)
```

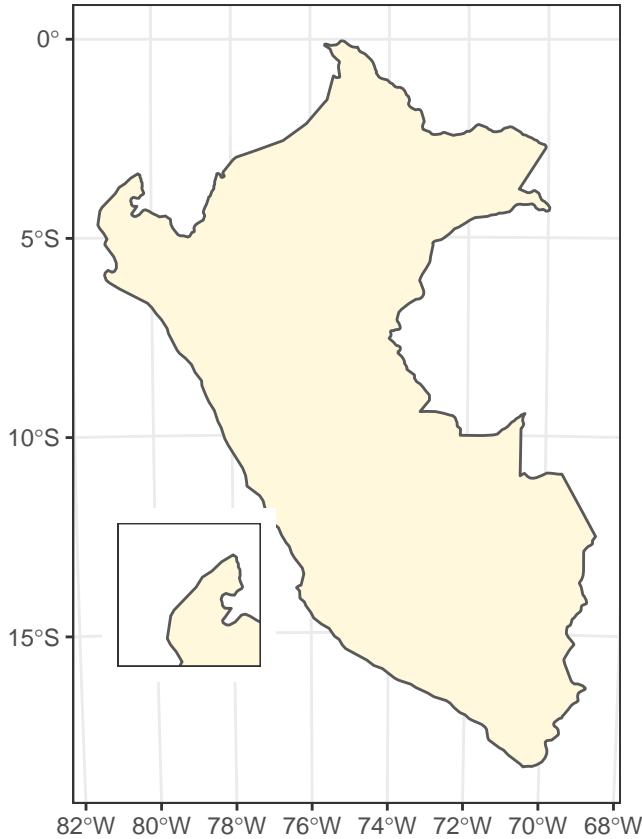
Inserción de Mapas:

```

peru <- subset(mundo, admin == "Peru")
map_peru <- ggplot(data = peru) +
  geom_sf(fill="cornsilk") +
  coord_sf(crs = st_crs(5387))
tumbes <- ggplot(data = peru) +
  geom_sf(fill="cornsilk") +
  coord_sf(xlim=c(-82, -80), ylim=c(-3,-5), datum = NA)

ggdraw(map_peru) +
  draw_plot(tumbes, width = 0.20, height = 0.20, x = 0.30, y = 0.20)

```



Comentarios Finales:

Pronto explicaremos la potencialidad geoespacial de `leaflet()`, `sf()` y `mapbox()` unidos a `plotly()` y `crosstalk()` entre otros para generar **mapas interactivos geoespaciales**. Para el análisis multiscience que considero filtros dinámicos en mapas, gráficos, tabla y cálculos estadísticos y geoestadístico interactuando simultáneamente se necesitarán algunas herramientas más que pronto veremos :D!!!.

Referencias Bibliográficas:

- Basic Reference from r-spatial.
- Revisando Sistemas de Coordenadas en R CRS.
- Working with Spatial Data Ecolog, Statistics, and Data Science with R
- Simple Future in R.
- Geocomputation with R.
- Spatial Data Science.
- Leaflet for R y Leaflet for R 2.
- tmap y tmap2.
- Spatial Cheatsheet.

- stats into R.
- Raster Data in R - The Basics.
- Intro to Raster Data.
- Earth Analytics Course: Learn Data Science
- Mapview popup functions.