INSP/ESPM
Escuela de Salud Pública de México

Despliegue de capas de información

José Luis Texcalac Sangrador

Procesamiento y visualización de datos espaciales en R

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- Municipios
  - 02mun.cpg
  - 02mun.dbf
  - 02mun.prj
  - 02mun.shp
  - 02mun.shx

Shapefile

Un shapefile se compone de varios Archivos.

Los mínimo son tres:

El .shp	Almacena las entidades geométricas.
El .shx	Almacena el índice de las entidades geométricas.
El .dbf	Es la base de datos, en formato dBASE

También pueden tener un .prj, .sbn, .sbx, .fbn, .fbx .ain, .aih, .shp.xml.

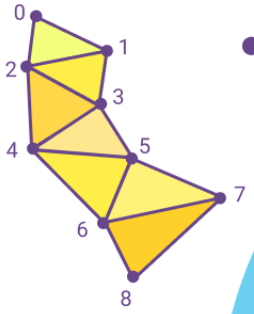
TIPO DE DATOS QUE ALMACENA.

Punto

Linea

Polígono

MultiPach



MultiPunto

Es el formato más extendido y popular entre la **comunidad GIS.**

HelpGIS

Importando datos con atributos espaciales en R

```
library(sf)
```

```
objeto <-
    st_read("ruta_archivo.shp",
        stringsAsFactors = FALSE,
        options = "ENCODING = WINDOWS-1252")
```

Alias:

```
read_sf("ruta_archivo.shp")
```

Mapa básico con ggplot

```
ggplot( ) +
   geom_sf( ) +
   theme( )
```

```
geom_sf(
  mapping = aes(),
  data = NULL,
  stat = "sf",
  position = "identity",
  na.rm = FALSE,
  show.legend = NA,
  inherit.aes = TRUE,
  ...
)
```

Exportar shapefile

```
st_write(objeto, "ruta/nombre_archivo.shp")
```

Importar capa de información

```
mun <-
    st_read("./shapefiles/cdmx_mun.shp") %>%
    clean_names() %>%
    print()
```

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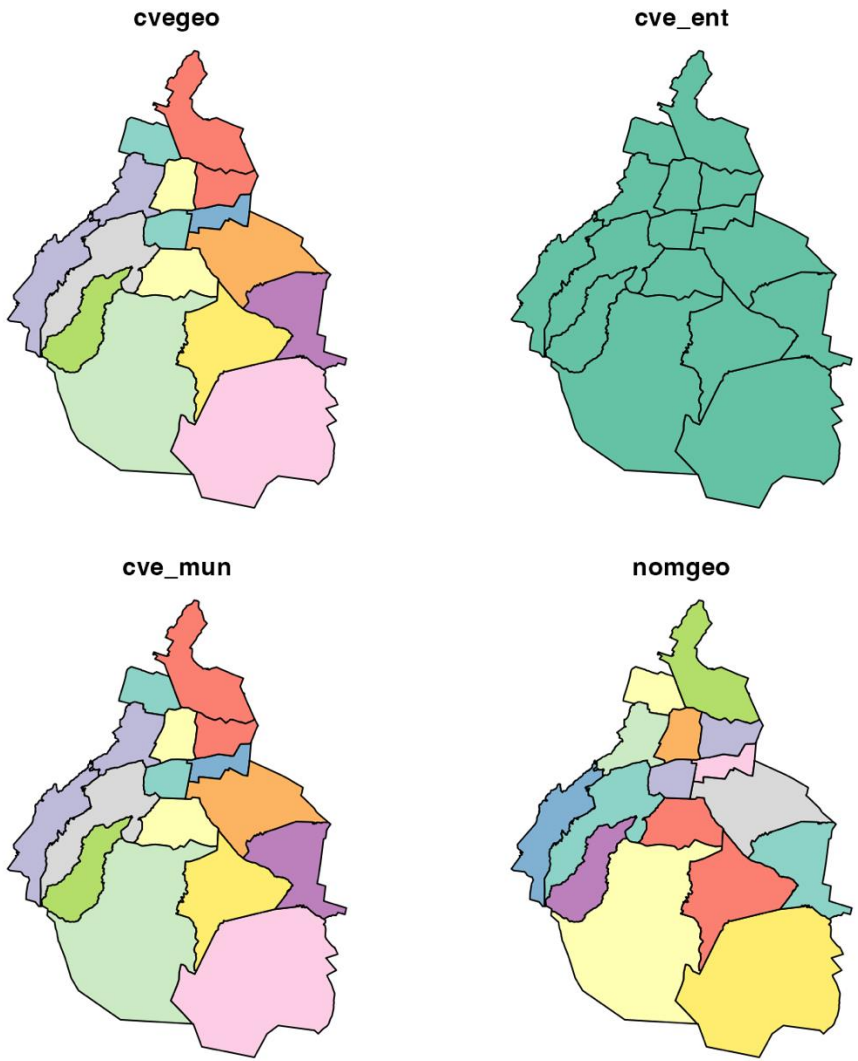
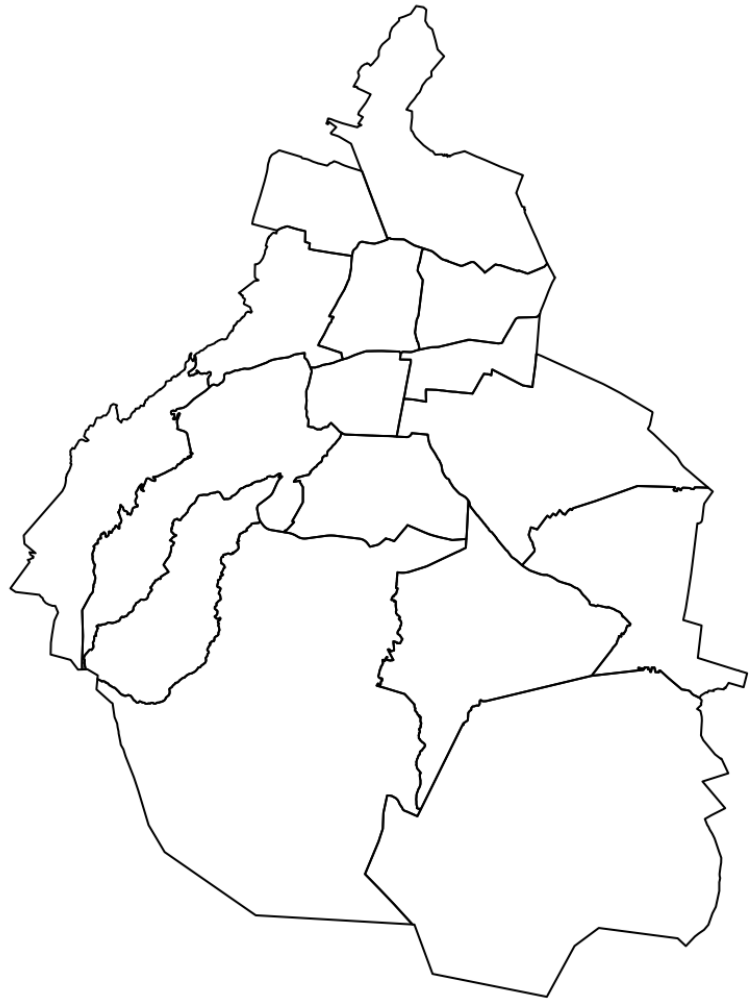
```
plot(mun)
```

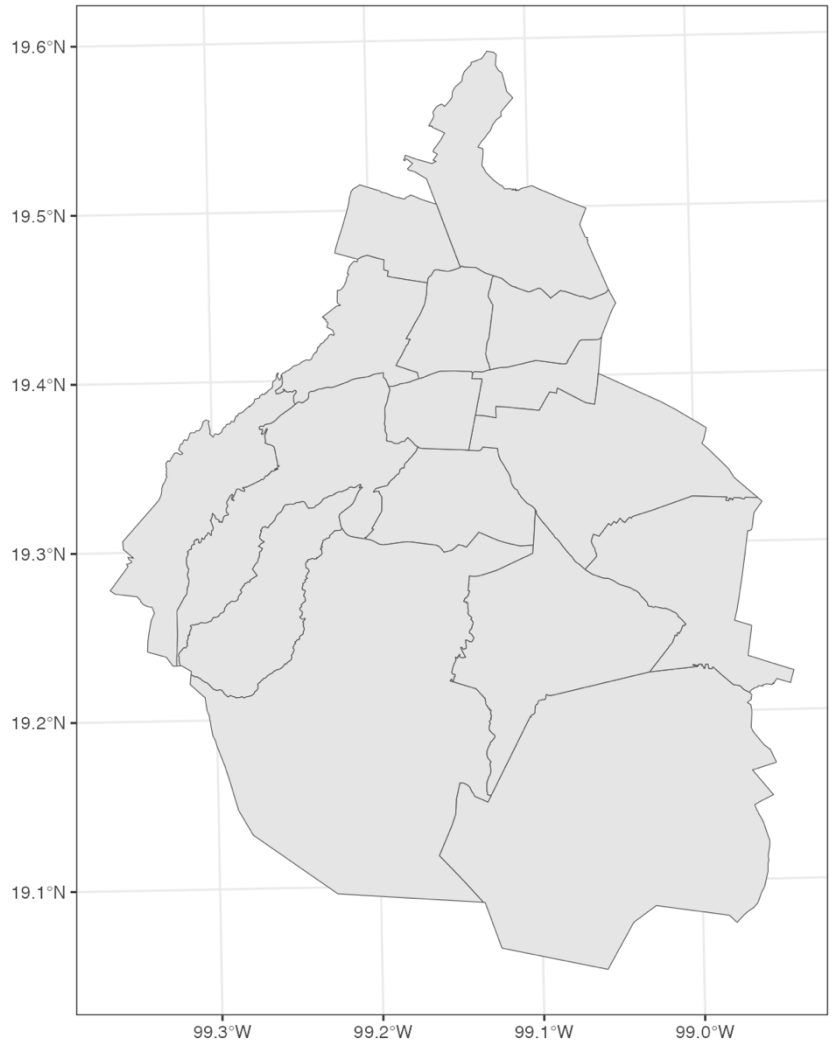



```
plot(st_geometry(mun))
```



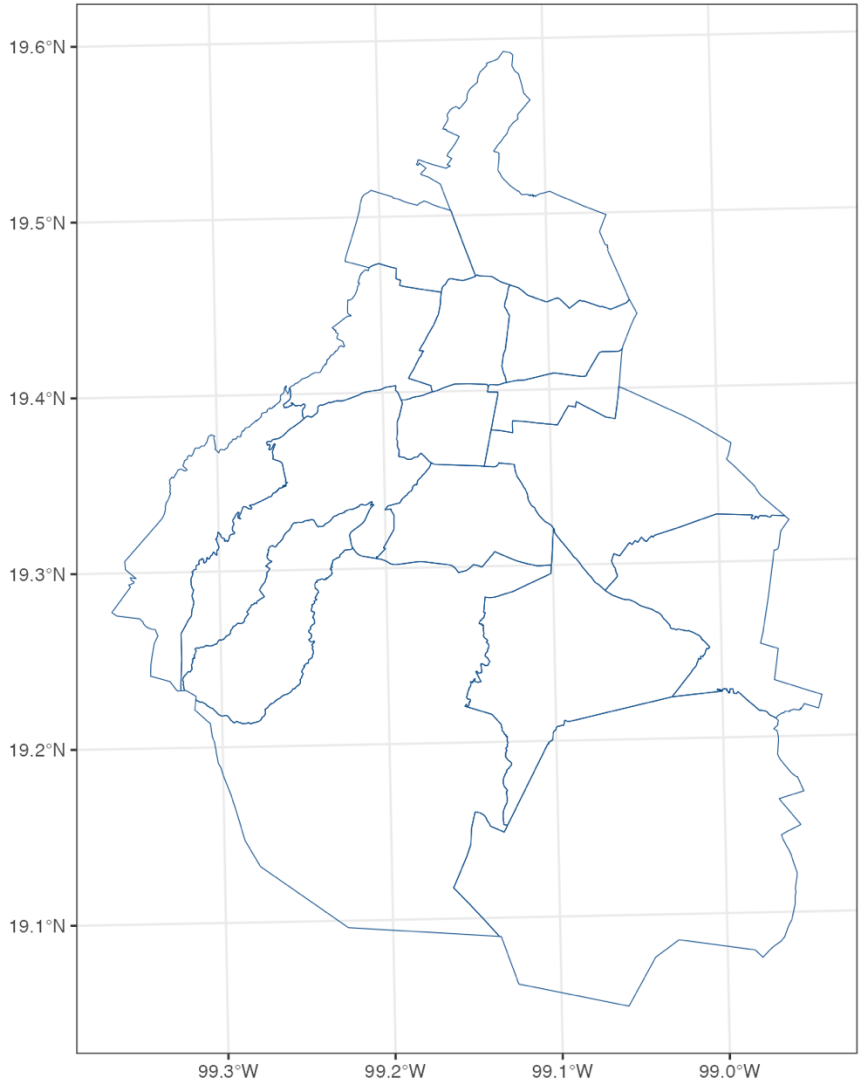
Visualizar capa de información con ggplot

```
ggplot(mun) +
    geom_sf(data = mun) +
    theme_bw()
```



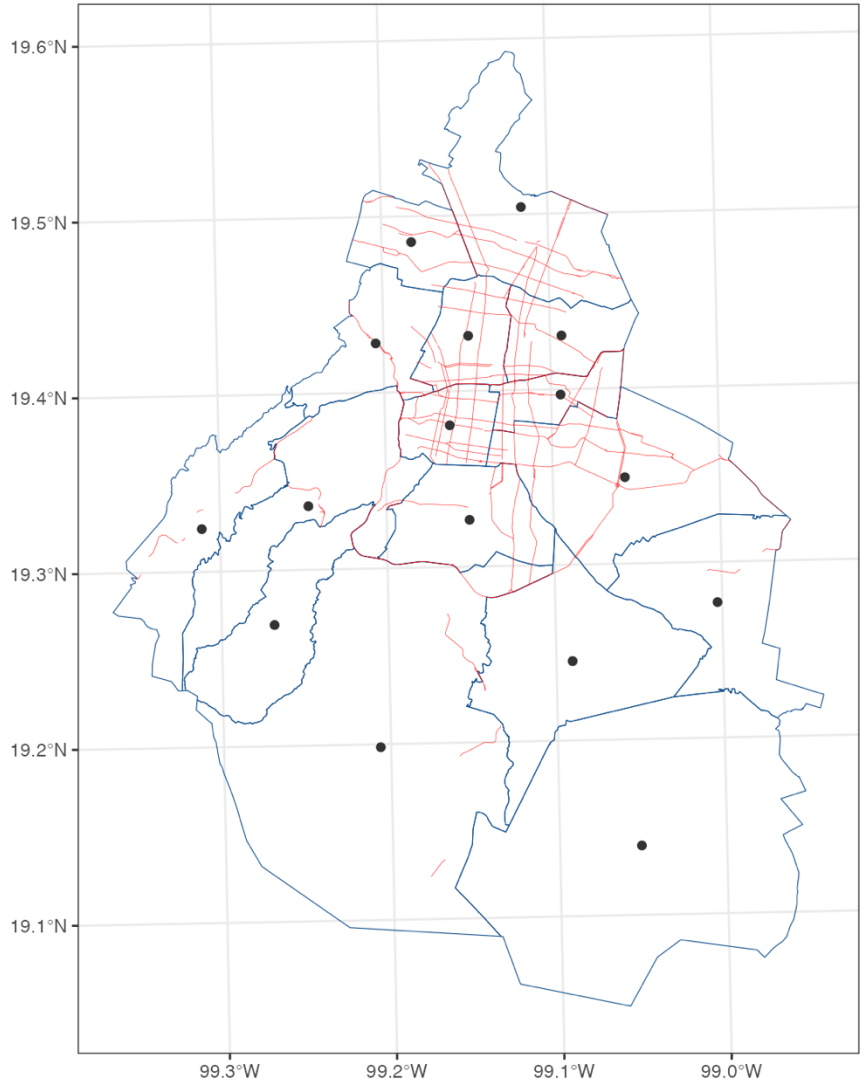
Visualizar capa de información con ggplot

```
ggplot() +
    geom_sf(data = mun,
            color = "dodgerblue4",
            fill = "transparent") +
    theme_bw()
```



Cartografía de puntos, líneas y polígonos

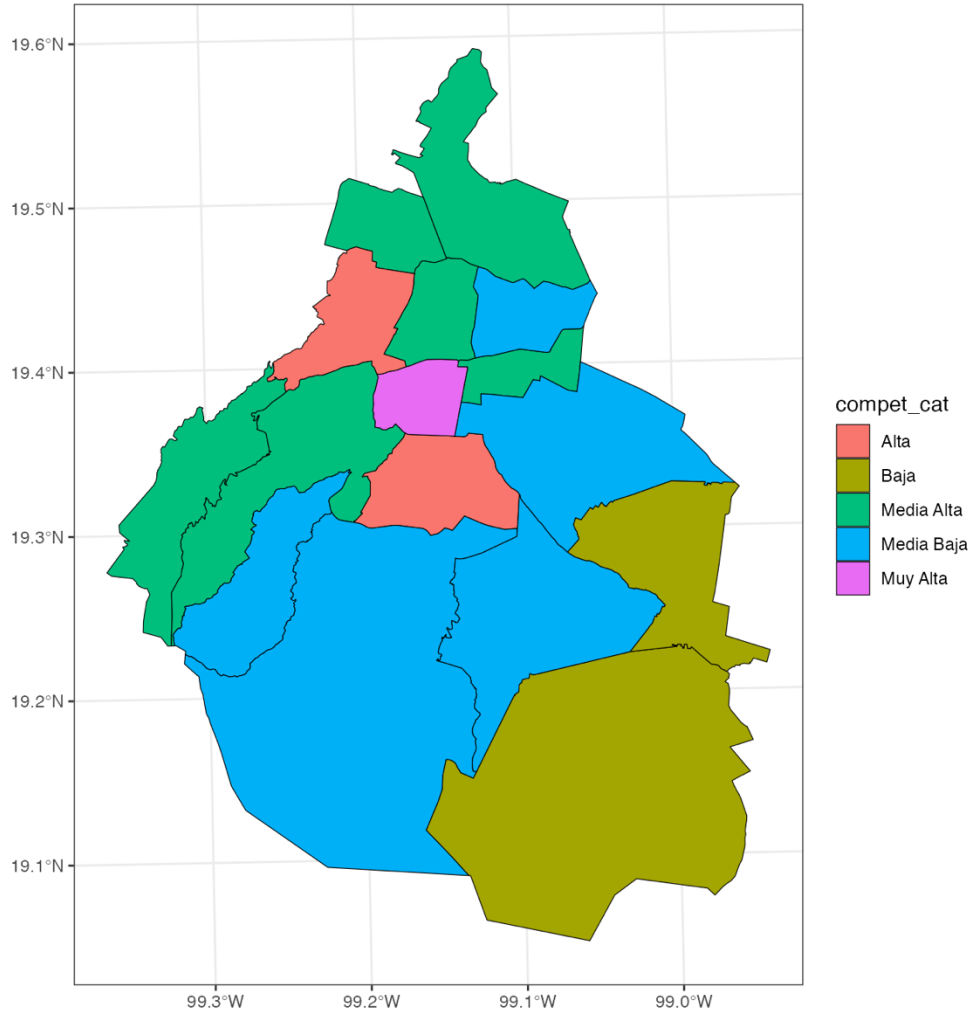
```
ggplot() +
    geom_sf(data = mun, color = "dodgerblue4", fill = "transparent") +
    geom_sf(data = vial, color = "red", linewidth = 0.1) +
    geom_sf(data = cent, color = "grey20") +
    theme_bw()
```



Cartografía temática de datos categóricos

cvegeo	compet_cat	compet_cont
<chr>	<chr>	<dbl>
09002	Media Alta	55.1
09003	Alta	64.7
09004	Media Alta	52.2
09005	Media Alta	50
09006	Media Alta	51
09007	Media Baja	41.5
09008	Media Baja	41.1
09009	Baja	30.1
09010	Media Alta	52.7
09011	Baja	33.6
09012	Media Baja	49.3
09013	Media Baja	36.4
09014	Muy Alta	78.3
09015	Media Alta	50.8
09016	Alta	74.4
09017	Media Baja	37.8

```
ggplot() +
    geom_sf(data = cdmx_imco,
                color = "black",
                aes(fill = compet_cat) +
    theme_bw()
```

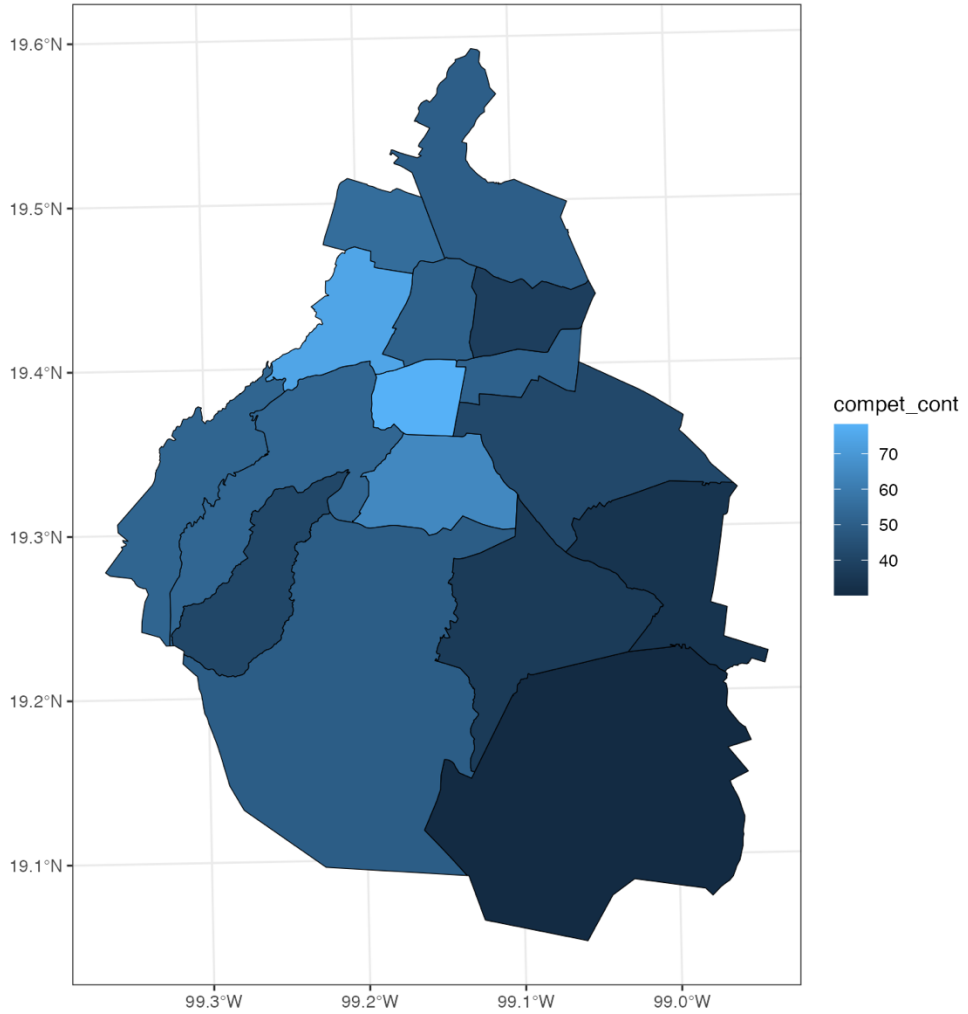


https://imco.org.mx/radiografia-chilanga-2024-competitividad-de-las-alcaldias/

Cartografía temática de datos continuos

cvegeo	compet_cat	compet_cont
<chr>	<chr>	<dbl>
09002	Media Alta	55.1
09003	Alta	64.7
09004	Media Alta	52.2
09005	Media Alta	50
09006	Media Alta	51
09007	Media Baja	41.5
09008	Media Baja	41.1
09009	Baja	30.1
09010	Media Alta	52.7
09011	Baja	33.6
09012	Media Baja	49.3
09013	Media Baja	36.4
09014	Muy Alta	78.3
09015	Media Alta	50.8
09016	Alta	74.4
09017	Media Baja	37.8

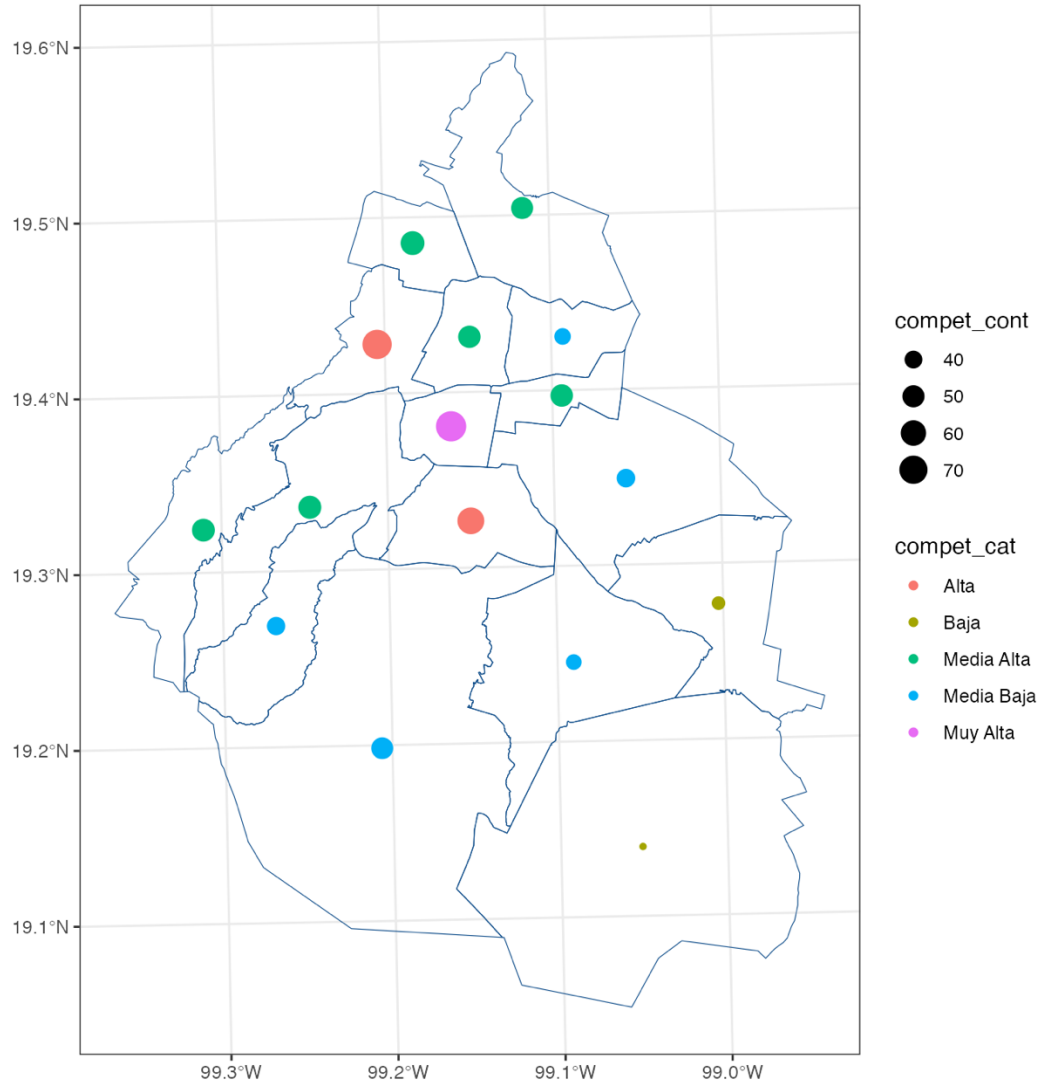
```
ggplot() +
    geom_sf(data = cdmx_imco,
                color = "black",
                aes(fill = compet_cont) +
    theme_bw()
```

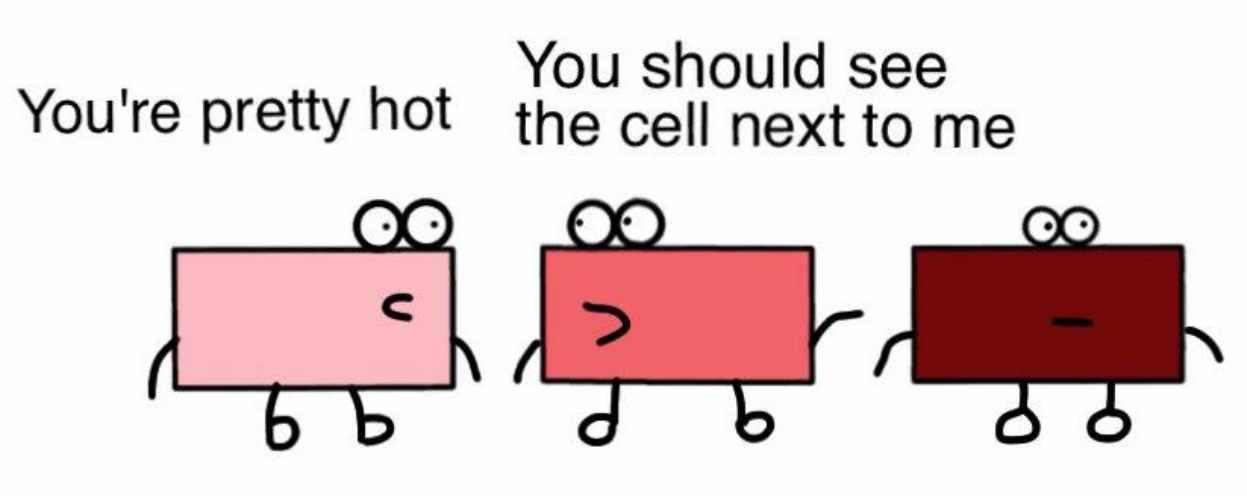


https://imco.org.mx/radiografia-chilanga-2024-competitividad-de-las-alcaldias/

Cartografía temática de dos variables

```
ggplot() +
    geom_sf(data = mun,
                color = "dodgerblue4",
                fill = "transparent") +
    geom_sf(data = cdmx_imco_c,
                aes(size = compet_cont,
                    color = compet_cat) +
    theme_bw()
```





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Cartografía temática

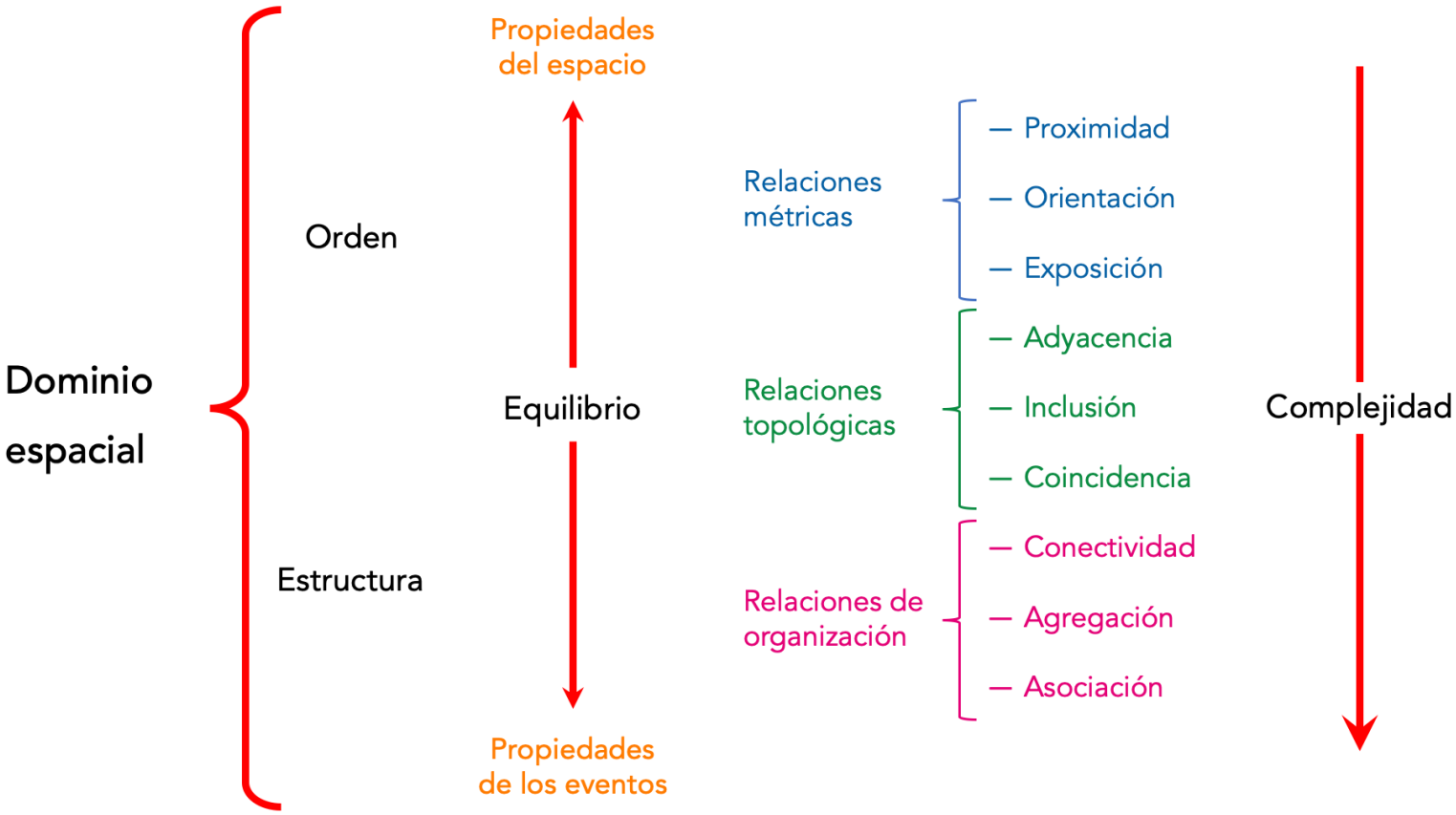
José Luis Texcalac Sangrador

Procesamiento y visualización de datos espaciales en R

Relaciones espaciales

- Son conceptos que surgen de la interacción entre el espacio y los eventos que en el ocurren.
- Se resumen en 9 tipos y tres grandes grupos.
  - Predominio de las propiedades del espacio
  - Equilibrio entre las propiedades del espacio y los eventos que en él ocurren.
  - Patrones espaciales definidos por las propiedades del espacio y los eventos que en él ocurren.

Relaciones espaciales



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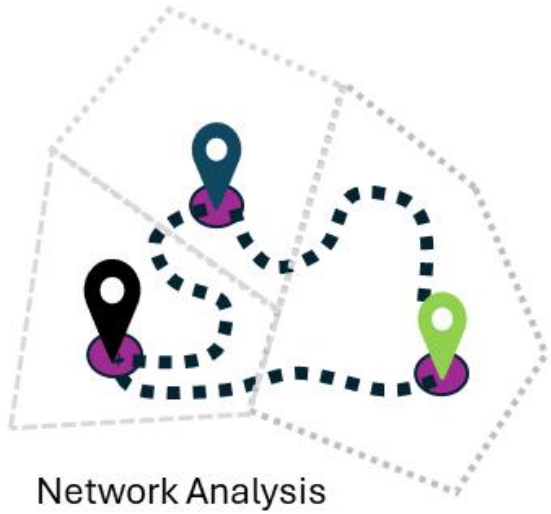
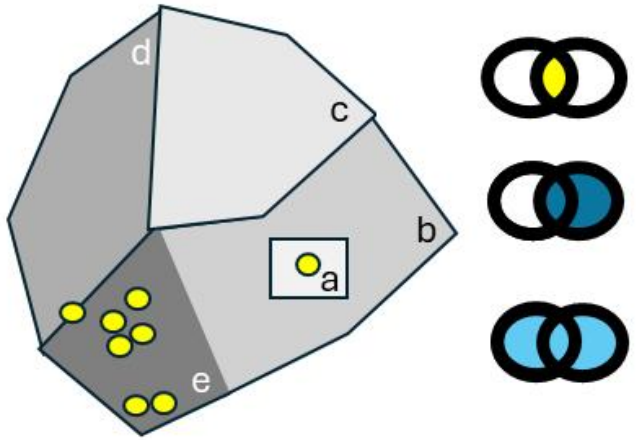
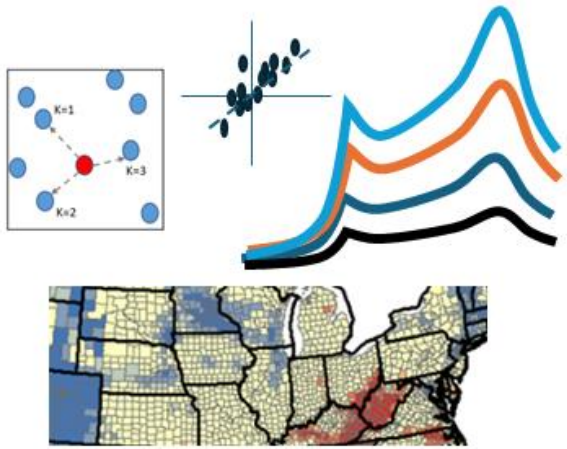
Measurement



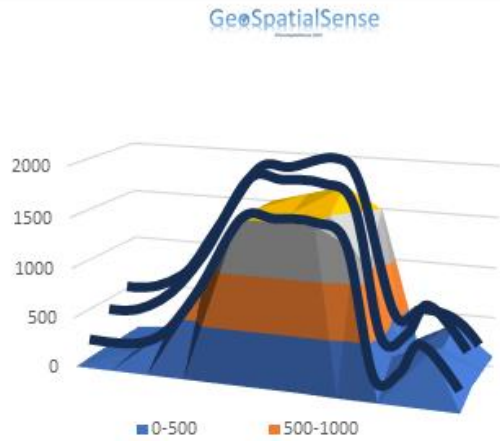
Network Analysis



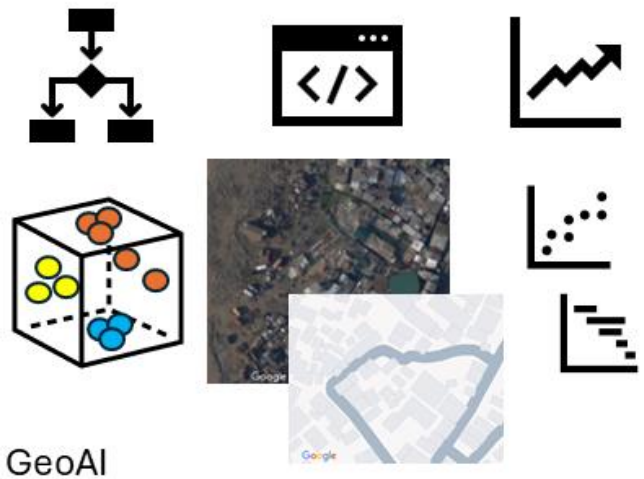
Topological Analysis



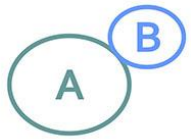
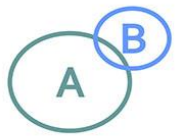
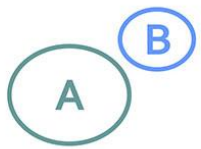
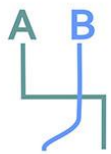
Spatial Statistical Analysis



Surface Analysis



GeoAI

Equals A is the same as B	
Touches A touches B	
Overlaps A and B have multiple points in common	
Contains A contains B	
Disjoint A shares nothing with B	
Covers A covers B (or vice versa)	
Crosses A and B have at least one point in common	

Spatial manipulation with sf: : CHEAT SHEET

The sf package provides a set of tools for working with geospatial vectors, i.e. points, lines, polygons, etc.

Geometric confirmation

st_contains(x, y, ...) Identifies if y is within x (i.e. point within polygon)

st_covered_by(x, y, ...) Identifies if x is completely within y (i.e. polygon completely within polygon)

st_covers(x, y, ...) Identifies if any point from x is outside of y (i.e. polygon outside polygon)

st_crosses(x, y, ...) Identifies if any geometry of x have commonalities with y

st_disjoint(x, y, ...) Identifies when geometries from x do not share space with y

st_equals(x, y, ...) Identifies if x and y share the same geometry

st_intersects(x, y, ...) Identifies if x and y geometry share any space

st_overlaps(x, y, ...) Identifies if geometries of x and y share space, are of the same dimension, but are not completely contained by each other

st_touches(x, y, ...) Identifies if geometries of x and y share a common point but their interiors do not intersect

st_within(x, y, ...) Identifies if x is in a specified distance to y

Geometric operations

st_boundary(x) Creates a polygon that encompasses the full extent of the geometry

st_buffer(x, dist, nQuadSegs) Creates a polygon covering all points of the geometry within a given distance

st_centroid(x, ..., of_largest_polygon) Creates a point at the geometric centre of the geometry

st_convex_hull(x) Creates geometry that represents the minimum convex geometry of x

st_line_merge(x) Creates linestring geometry from sewing multi linestring geometry together

st_node(x) Creates nodes on overlapping geometry where nodes do not exist

st_point_on_surface(x) Creates a point that is guarenteed to fall on the surface of the geometry

st_polygonize(x) Creates polygon geometry from linestring geometry

st_segmentize(x, dfMaxLength, ...) Creates linesting geometry from x based on a specified length

st_simplify(x, preserveTopology, dTolerance) Creates a simplified version of the geometry based on a specified tolerance

Geometry creation

st_triangulate(x, dTolerance, bOnlyEdges) Creates polygon geometry as triangles from point geometry

st_voronoi(x, envelope, dTolerance, bOnlyEdges) Creates polygon geometry covering the envelope of x, with x at the centre of the geometry

st_point(x, c(numeric vector), dim = "XYZ") Creating point geometry from numeric values

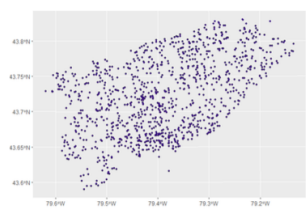
st_multipoint(x = matrix(numeric values in rows), dim = "XYZ") Creating multi point geometry from numeric values

st_linestring(x = matrix(numeric values in rows), dim = "XYZ") Creating linestring geometry from numeric values

st_multilinestring(x = list(numeric matricesin rows), dim = "XYZ") Creating multi linestring geometry from numeric values

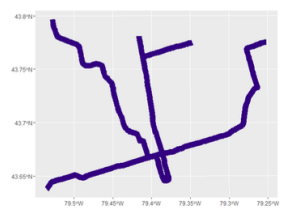
st_polygon(x = list(numeric matrices in rows), dim = "XYZ") Creating polygon geometry from numeric values

st_multipolygon(x = list(numeric matrices in rows), dim = "XYZ") Creating multi polygon geometry from numeric values



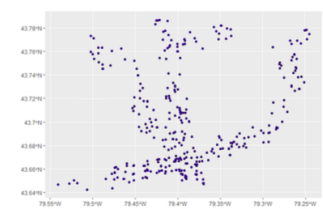
```
ggplot() +
  geom_sf(data = schools)
```

+



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

=>



```
ggplot() +
  geom_sf(data = st_intersection(schools, st_buffer(subway, 1000)))
```

This cheatsheet presents the sf package [Edzer Pebesma 2018] in version 0.6.3. See https://github.com/r-spatial/sf for more details.

https://github.com/rstudio/cheatsheets/blob/main/sf.pdf

Spatial manipulation with sf: : CHEAT SHEET

The sf package provides a set of tools for working with geospatial vectors, i.e. points, lines, polygons, etc.

Geometry operations

st_contains(x, y, ...) Identifies if y is within x (i.e. point within polygon)

st_crop(x, y, ..., xmin, ymin, xmax, ymax) Creates geometry of x that intersects a specified rectangle

st_difference(x, y) Creates geometry from x that does not intersect with y

st_intersection(x, y) Creates geometry of the shared portion of x and y

st_sym_difference(x, y) Creates geometry representing portions of x and y that do not intersect

st_snap(x, y, tolerance) Snap nodes from geometry x to geometry y

st_union(x, y, ..., by_feature) Creates multiple geometries into a a single geometry, consisiting of all geometry elements

Geometric measurement

st_area(x) Calculate the surface area of a polygon geometry based on the current coordinate reference system

st_distance(x, y, ..., dist_fun, by_element, which) Calculates the 2D distance between x and y based on the current coordinate system

st_length(x) Calculates the 2D length of a geometry based on the current coordinate system

Misc operations

st_as_sf(x, ...) Create a sf object from a non-geospatial tabular data frame

st_cast(x, to, ...) Change x geometry to a different geometry type

st_coordinates(x, ...) Creates a matrix of coordinate values from x

st_crs(x, ...) Identifies the coordinate reference system of x

st_join(x, y, join, FUN, suffix, ...) Performs a spatial left or inner join between x and y

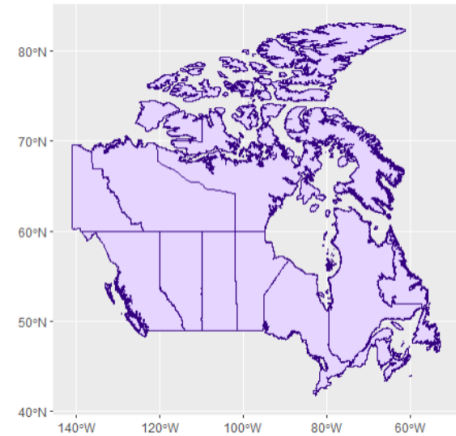
st_make_grid(x, cellsize, offset, n, crs, what) Creates rectangular grid geometry over the bounding box of x

st_nearest_feature(x, y) Creates an index of the closest feature between x and y

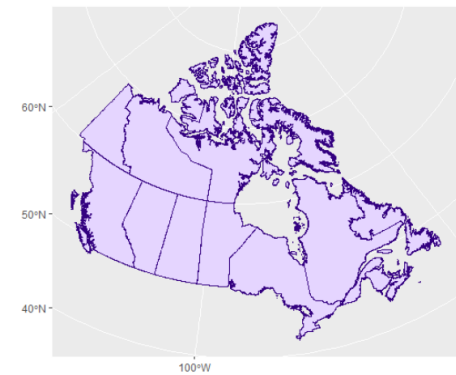
st_nearest_points(x, y, ...) Returns the closest point between x and y

st_read(dsn, layer, ...) Read file or database vector dataset as a sf object

st_transform(x, crs, ...) Convert coordinates of x to a different coordinate reference system




```
ggplot() +
  geom_sf(data = cdn) +
  coord_sf(crs = st_crs(4326))
```




```
ggplot() +
  geom_sf(data = cdn) +
  coord_sf(crs = st_crs(3347))
```

This cheatsheet presents the sf package [Edzer Pebesma 2018] in version 0.6.3. See https://github.com/r-spatial/sf for more details.

https://github.com/rstudio/cheatsheets/blob/main/sf.pdf

Proyecciones en R

Siempre nuestro planteamiento incial debería ser

¿son iguales las proyecciones de las capas que utilizaré?

```
> st_crs(capa)
```

Me indica la proyección de mi capa

```
identical(st_crs(capa1), st_crs(capa2))
```

Identifico si las proyecciones de dos capas son similares

Todo análisis espacial debe realizarse con

capas que tienen la misma proyección.

Reproyectando una capa en R

Proyección a la cual se quiere reproyectar la capa

```
st_transform(capa , crs)
```

Nombre de la capa a reproyectar

INEGI: 6372

WGS84: 4326

```
st_transform(cdmx_shp , 6372)
```

Spatial manipulation with sf: : CHEAT SHEET

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st_crosses(x, y, ...) Identifies if any geometry of x have commonalities with y

st_disjoint(x, y, ...) Identifies when geometries from x do not share space with y

st_equals(x, y, ...) Identifies if x and y share the same geometry

st_intersects(x, y, ...) Identifies if x and y geometry share any space

st_overlaps(x, y, ...) Identifies if geometries of x and y share space, are of the same dimension, but are not completely contained by each other

st_touches(x, y, ...) Identifies if geometries of x and y share a common point but their interiors do not intersect

st_within(x, y, ...) Identifies if x is in a specified distance to y

Geometric operations

st_boundary(x) Creates a polygon that encompasses the full extent of the geometry

st_buffer(x, dist, nQuadSegs) Creates a polygon covering all points of the geometry within a given distance

st_centroid(x, ..., of_largest_polygon) Creates a point at the geometric centre of the geometry

st_convex_hull(x) Creates geometry that represents the minimum convex geometry of x

st_line_merge(x) Creates linestring geometry from sewing multi linestring geometry together

st_node(x) Creates nodes on overlapping geometry where nodes do not exist

st_point_on_surface(x) Creates a point that is guarenteed to fall on the surface of the geometry

st_polygonize(x) Creates polygon geometry from linestring geometry

st_segmentize(x, dfMaxLength, ...) Creates linesting geometry from x based on a specified length

st_simplify(x, preserveTopology, dTolerance) Creates a simplified version of the geometry based on a specified tolerance

Geometry creation

st_triangulate(x, dTolerance, bOnlyEdges) Creates polygon geometry as triangles from point geometry

st_voronoi(x, envelope, dTolerance, bOnlyEdges) Creates polygon geometry covering the envolope of x, with x at the centre of the geometry

st_point(x, c(numeric vector), dim = "XYZ") Creating point geometry from numeric values

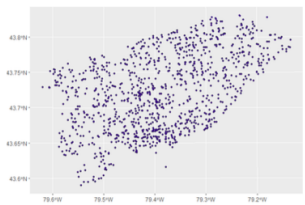
st_multipoint(x = matrix(numeric values in rows), dim = "XYZ") Creating multi point geometry from numeric values

st_linestring(x = matrix(numeric values in rows), dim = "XYZ") Creating linestring geometry from numeric values

st_multilinestring(x = list(numeric matricesin rows), dim = "XYZ") Creating multi linestring geometry from numeric values

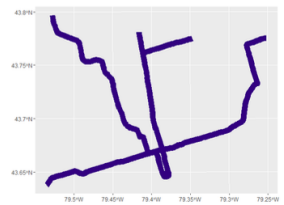
st_polygon(x = list(numeric matrices in rows), dim = "XYZ") Creating polygon geometry from numeric values

st_multipolygon(x = list(numeric matrices in rows), dim = "XYZ") Creating multi polygon geometry from numeric values



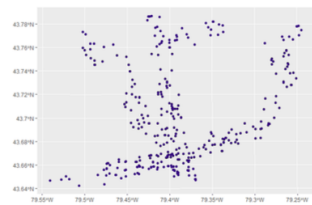
```
ggplot() +
  geom_sf(data = schools)
```

+



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

=>



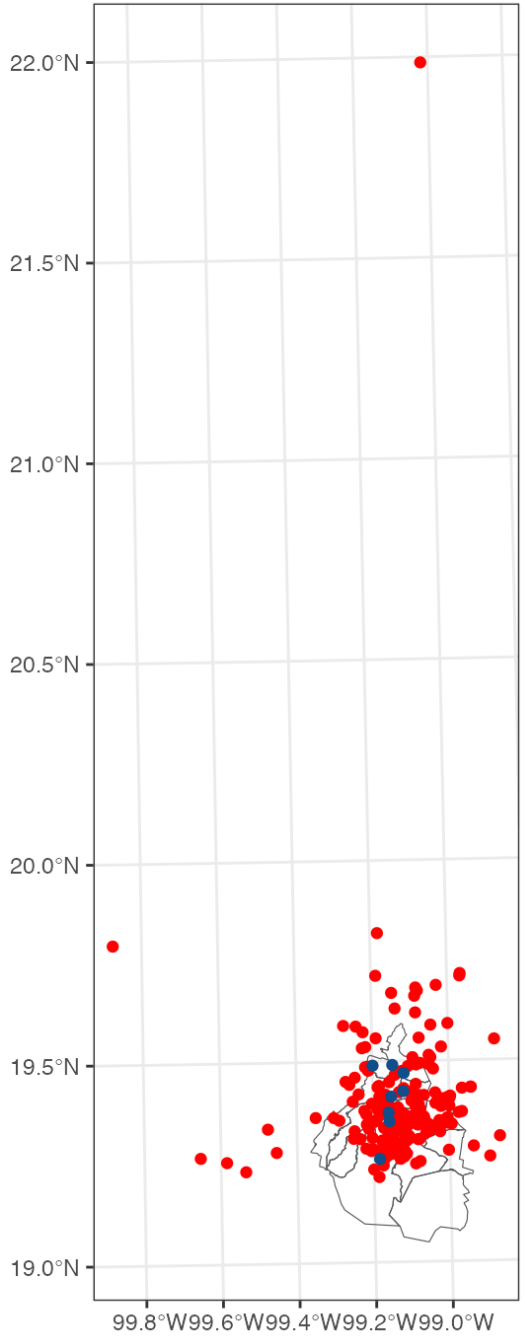
```
ggplot() +
  geom_sf(data = st_intersection(schools, st_buffer(subway, 1000)))
```

This cheatsheet presents the sf package [Edzer Pebesma 2018] in version 0.6.3. See https://github.com/r-spatial/sf for more details.

Su turno...

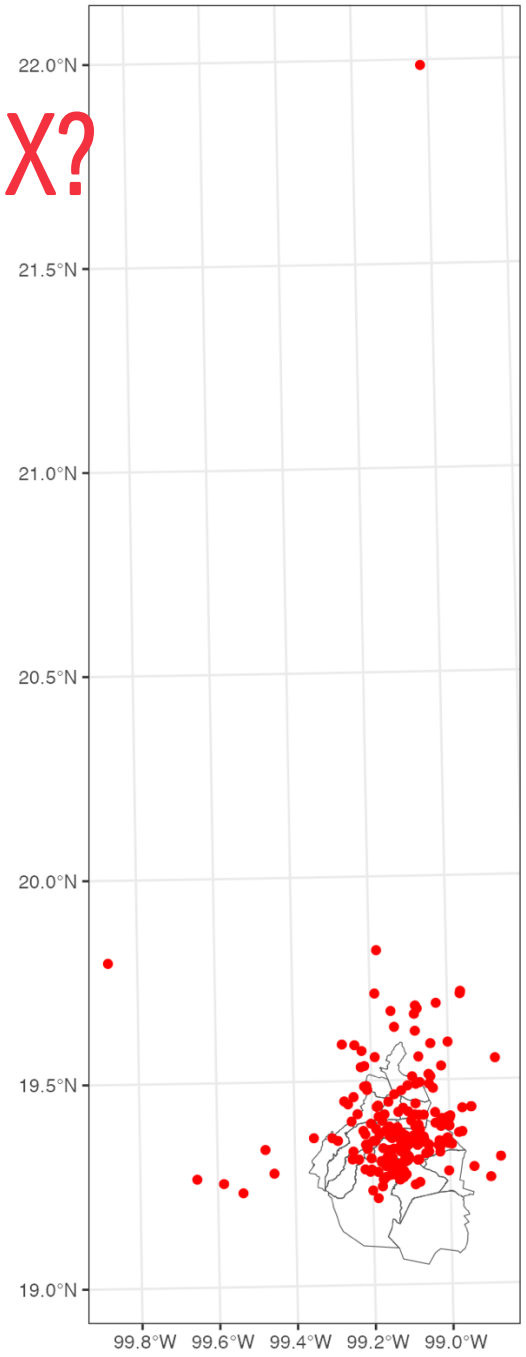
- Importe la capa de municipios de la CDMX que descargó de INEGI (cdmx_mun)
- Importe la capa de sitios (sitios)
- Importe la capa de monitores (monit)
- ¿qué sigue?
- Genere un mapa con ambas capas

```
ggplot() +
    geom_sf(data = cdmx_mun,
                fill = "transparent") +
    geom_sf(data = sitios,
                color = "red") +
    geom_sf(data = monit,
                color = ”dodgerblue4") +
    theme_bw()
```



¿Qué folios están dentro de CDMX?

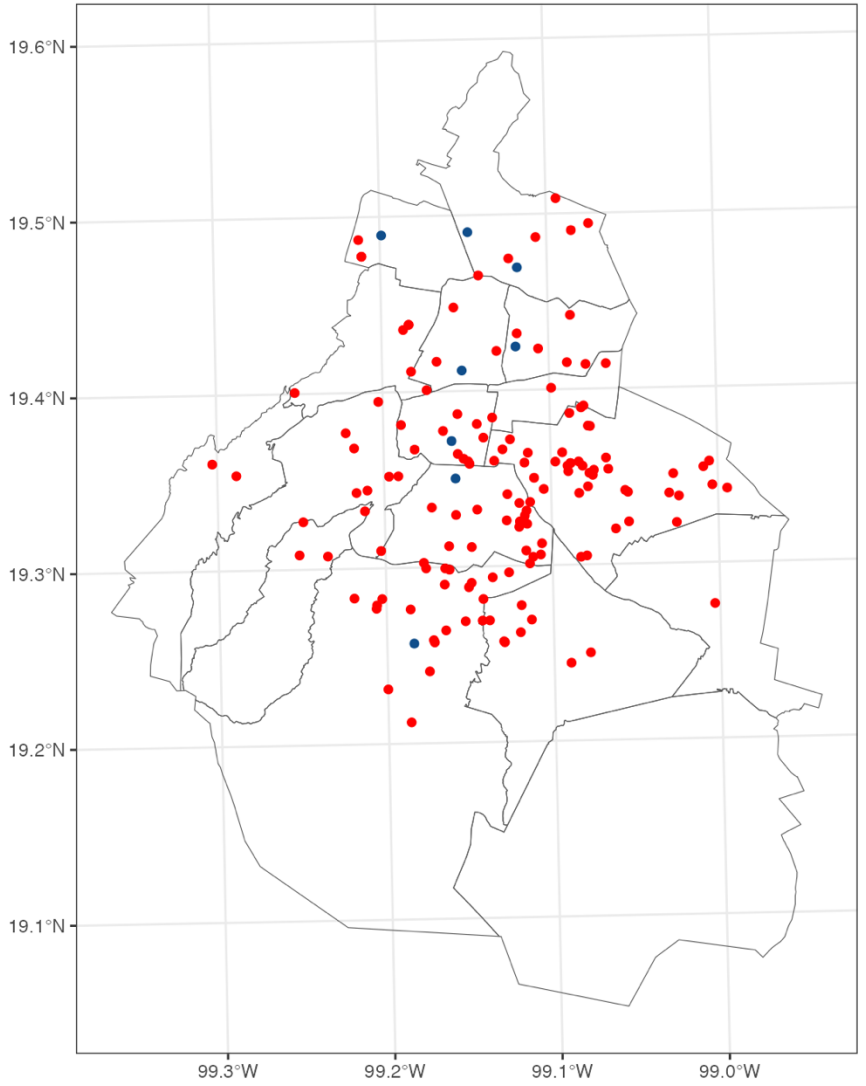
```
sitios_cdmx <-
  st_filter(sitios, cdmx) %>%
  print()
```



¿Qué folios están dentro de CDMX?

```
sitios_cdmx <-
  st_filter(sitios, cdmx) %>%
  print()
```

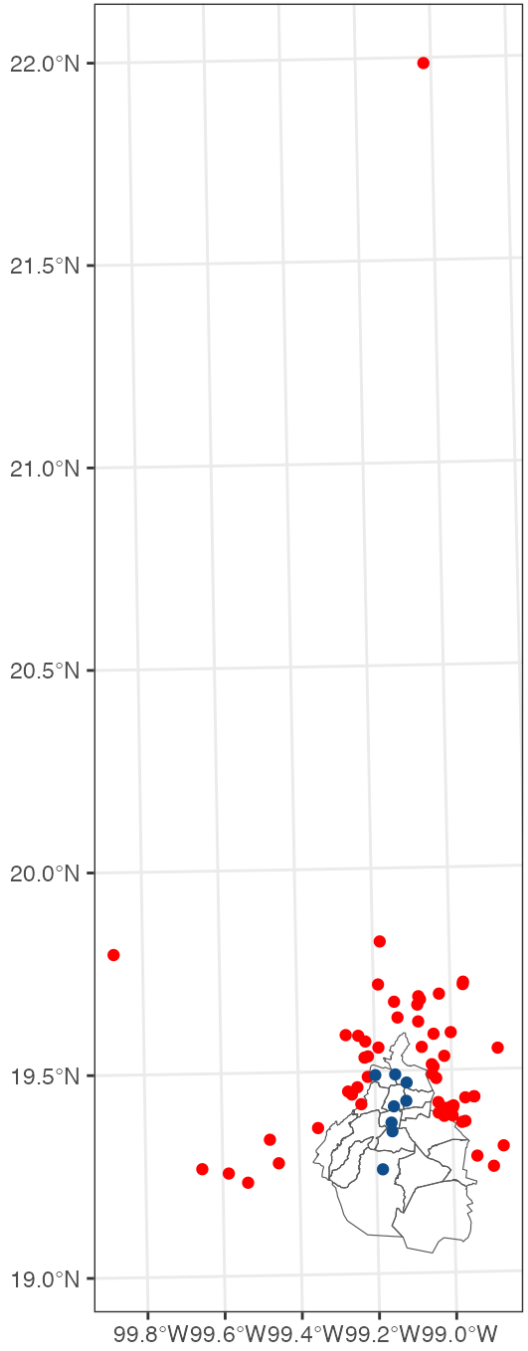
```
ggplot() +
    geom_sf(data = cdmx_mun, fill = "transparent") +
    geom_sf(data = sitios_cdmx, color = "red") +
    geom_sf(data = monit, color = "dodgerblue4") +
    theme_bw()
```



¿Qué folios están fuera de CDMX?

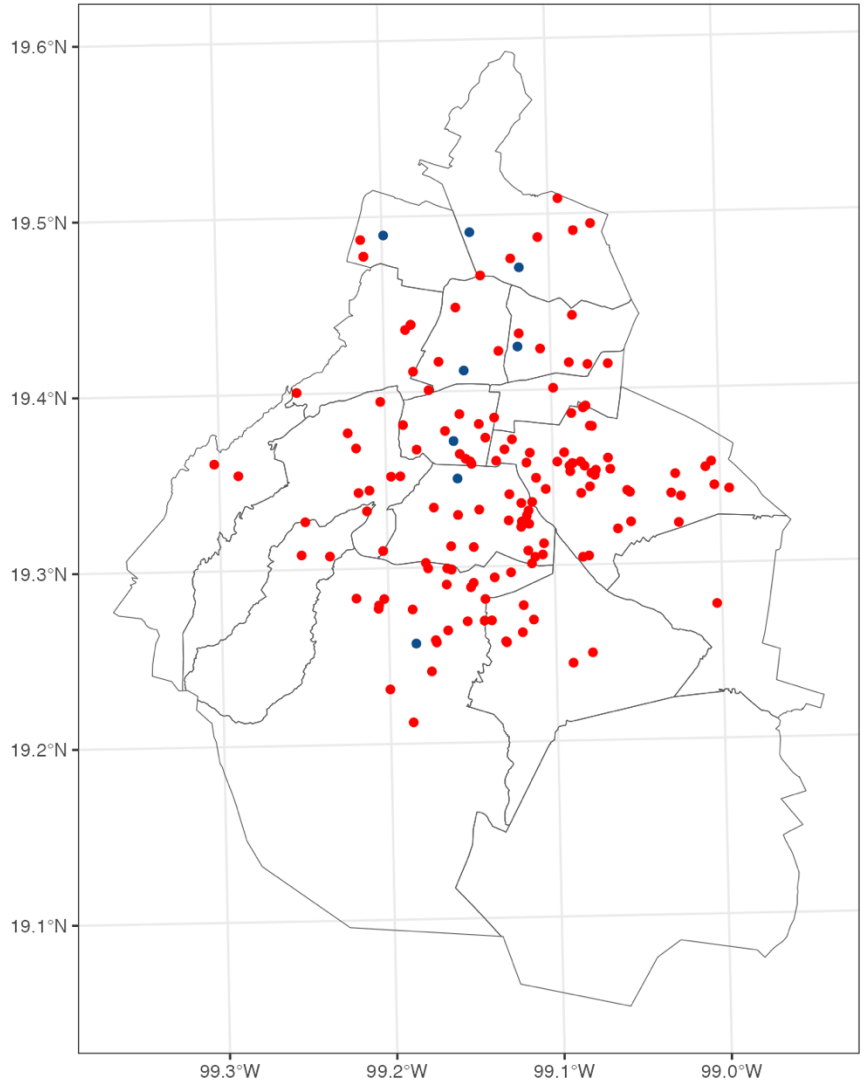
```
sitios_no_cdmx <-
  st_filter(sitios, cdmx_ent, .predicate = st_disjoint) %>%
  print()
```

```
ggplot() +
    geom_sf(data = cdmx_ent, fill = "transparent") +
    geom_sf(data = sitios_cdmx, color = "red") +
    geom_sf(data = monit, color = "dodgerblue4") +
    theme_bw()
```



¿A qué alcaldía corresponde cada folio?

```
st_join(sitios_cdmx, cdmx_mun, join = st_within)
```

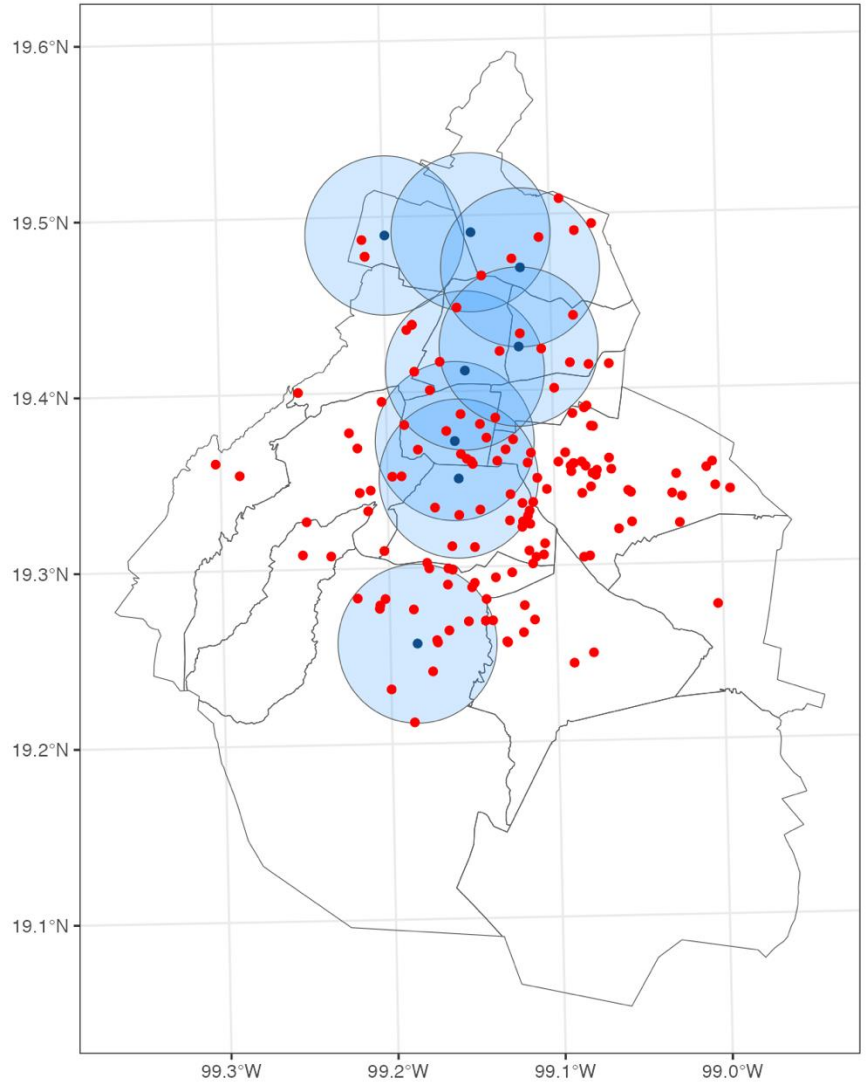


Área de influencia de un punto (buffer)

```
buf_monit <-
  st_buffer(monit, 5000, nQuadSegs = 30) %>%
  print()
```

¿A qué buffer corresponde cada sitio?

¿cuántos sitios quedaron fuera de buffers?



¿En qué buffer o buffers cae cada folio?

```
st_join(pts_cdmx,
        buf_monit,
        join = st_within)
```

```
Simple feature collection with 183 features and 6 fields
Geometry type: POINT
Dimension:     XY
Bounding box:  xmin: 2782545 ymin: 804611.1 xmax: 2814894 ymax: 837532.4
Projected CRS: Mexico ITRF2008 / LCC
First 10 features:
    folio cvegeo cve_ent cve_mun            nomgeo site                  geometry
1    1754  09005      09     005 Gustavo A. Madero  LVI POINT (2805067 835529.4)
2    2722  09012      09     012           Tlalpan <NA> POINT (2799581 812358.5)
3    8758  09003      09     003          Coyoacán  COY   POINT (2801880 817228)
4    2192  09007      09     007        Iztapalapa <NA> POINT (2806450 820158.9)
5    3161  09005      09     005 Gustavo A. Madero  IMP   POINT (2801141 833745)
5.1  3161  09005      09     005 Gustavo A. Madero  LVI   POINT (2801141 833745)
6    8830  09012      09     012           Tlalpan <NA> POINT (2801194 814034.4)
7    1938  09007      09     007        Iztapalapa <NA>   POINT (2806145 819439)
8    8606  09007      09     007        Iztapalapa <NA> POINT (2804096 820989.6)
9    1967  09003      09     003          Coyoacán  BJU POINT (2797862 817634.2)
```

¿Cuál es la distancia entre folios y estaciones de monitoreo?

```
dist <-
  st_distance(pts_cdmx, monit) %>%
  print()
```

El resultado es una matriz

```
Units: [m]
           [,1]       [,2]      [,3]      [,4]      [,5]      [,6]       [,7]       [,8]
 [1,] 11916.406 15220.0657 17203.571 11168.206  6499.460  4118.933  8096.5364 27769.131
 [2,] 23716.736 10120.7845  7764.506 14413.920 23056.665 20931.504 15984.9149  5166.418
 [3,] 19966.993  6634.5660  4865.522 10162.473 18464.174 15957.669 10992.1981 10145.339
 [4,] 20065.468  9121.5589  8624.523 10519.264 17151.901 13871.307  9408.8064 15428.959
 [5,]  8115.284 12006.8501 14213.861  7620.333  3055.007   777.837  5546.9032 24897.482
 [6,] 22629.547  9002.6512  6782.020 13018.107 21519.217 19156.235 14187.6347  7449.255
 [7,] 20414.776  9025.2479  8330.349 10755.164 17661.391 14452.289  9888.0949 14716.066
 [8,] 17925.016  6644.6396  6358.045  8200.982 15427.603 12431.889  7648.5939 14461.506
 [9,] 18173.834  4653.5061  2288.633  9080.574 17772.795 16012.335 11220.4678  8491.929
[10,] 13391.319  2945.5145  4468.799  3516.512 11741.957  9556.685  4695.8396 15015.401
```

¿Qué nos falta?

Transformar a tibble

```
dist <- as_tibble(dist)
```

Nombres de columna

```
names(dist) <- monit$site
```

Recuperar el folio

```
bind_cols(sitios_cdmx, dist)
```


```
st_distance(pts_cdmx, monit) %>%
  as_tibble() %>%
  rename_all(list(~monit$site)) %>%
  bind_cols(pts_cdmx)
```

```
Simple feature collection with 143 features and 9 fields
Geometry type: POINT
Dimension:     XY
Bounding box:  xmin: 2782545 ymin: 804611.1 xmax: 2814894 ymax: 837532.4
Projected CRS: Mexico ITRF2008 / LCC
First 10 features:
   folio       AZC       BJU       COY       HGM       IMP       LVI       MER       TPN                  geometry
1   1754 11916.406 15220.066 17203.571 11168.206  6499.460  4118.933  8096.536 27769.131 POINT (2805067 835529.4)
2   2722 23716.736 10120.784  7764.506 14413.920 23056.665 20931.504 15984.915  5166.418 POINT (2799581 812358.5)
3   8758 19966.993  6634.566  4865.522 10162.473 18464.174 15957.669 10992.198 10145.339   POINT (2801880 817228)
4   2192 20065.468  9121.559  8624.523 10519.264 17151.901 13871.307  9408.806 15428.959 POINT (2806450 820158.9)
5   3161  8115.284 12006.850 14213.861  7620.333  3055.007   777.837  5546.903 24897.482   POINT (2801141 833745)
6   8830 22629.547  9002.651  6782.020 13018.107 21519.217 19156.235 14187.635  7449.255 POINT (2801194 814034.4)
7   1938 20414.776  9025.248  8330.349 10755.164 17661.391 14452.289  9888.095 14716.066   POINT (2806145 819439)
8   8606 17925.016  6644.640  6358.045  8200.982 15427.603 12431.889  7648.594 14461.506 POINT (2804096 820989.6)
9   1967 18173.834  4653.506  2288.633  9080.574 17772.795 16012.335 11220.468  8491.929 POINT (2797862 817634.2)
10  1913 13391.319  2945.514  4468.799  3516.512 11741.957  9556.685  4695.840 15015.401 POINT (2800127 823754.8)
```