SPAG

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SPAG Index of Spatial Agglomeration notebook

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SPAG: Index of Spatial Agglomeration

$$SPAG = I_{\text{coverage}} * I_{\text{distance}} * I_{\text{overlap}}$$

Survey Data

Load R packages

```
library(sf)
library(dplyr)
library(tidyr)
library(ggplot2)
```

Load survey data

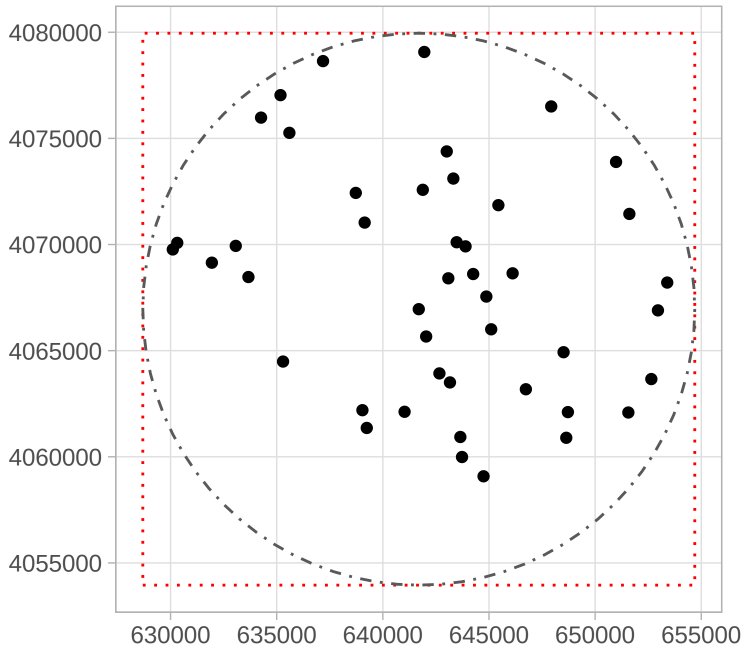
```r
# check the layes name in the geopackage
# st_layers("./data/vect/data.gpkg")

# load all sites fron TBS survey
sites = st_read("../data/vect/data.gpkg", layer = "tbs_sites_point", quiet = TRUE)

# look at the data
head(sites, 1)
```

```
Simple feature collection with 1 feature and 11 fields
Geometry type: POINT
Dimension:     XY
Bounding box:  xmin: 641692.6 ymin: 4066955 xmax: 641692.6 ymax: 4066955
Projected CRS: WGS 84 / UTM zone 37N
         id size_ha start_date end_date longitude latitude
1 TBS_1_0_0      45       -900     -300  40.58699 36.73775
                 source code   period        name tell                     geom
1 Ur and Wilkinson 2008  TBS Iron Age Tell Beydar TRUE POINT (641692.6 4066955)
```

```r
# iron age sites

sites_IA = sites %>%
  filter(period == "Iron Age") %>%
  select(id, size_ha)

# load survey extent
survey = st_read("../data/vect/data.gpkg", layer = "tbs_survey_extent", quiet = TRUE)

# create a bounding box around sites
bbox = st_bbox(survey) %>% st_as_sfc()
```

Map data

```r
ggplot() +
  geom_sf(data = bbox, fill = NA, linetype = 21, color = "red") +
  geom_sf(data = survey, fill = NA, linetype = 22) +
  geom_sf(data = sites_IA) +
  coord_sf(datum = st_crs(sites)) +
  theme_light()
```



Calculate **Agricultural Sustaining Areas** for emprical dataset

```
sites_emp = sites_IA %>%
  mutate(
    pop = round(100 * size_ha),   # calculate population - 100 people per hectar
    agr_zone_h = pop * 3,         # calculate agricultural sustaining area = 3h per person
    agr_zone_m = agr_zone_h * 10000, # hectares to meters
    agr_radi_m = round(sqrt(agr_zone_m/pi))
  )

head(sites_emp, 2)
```

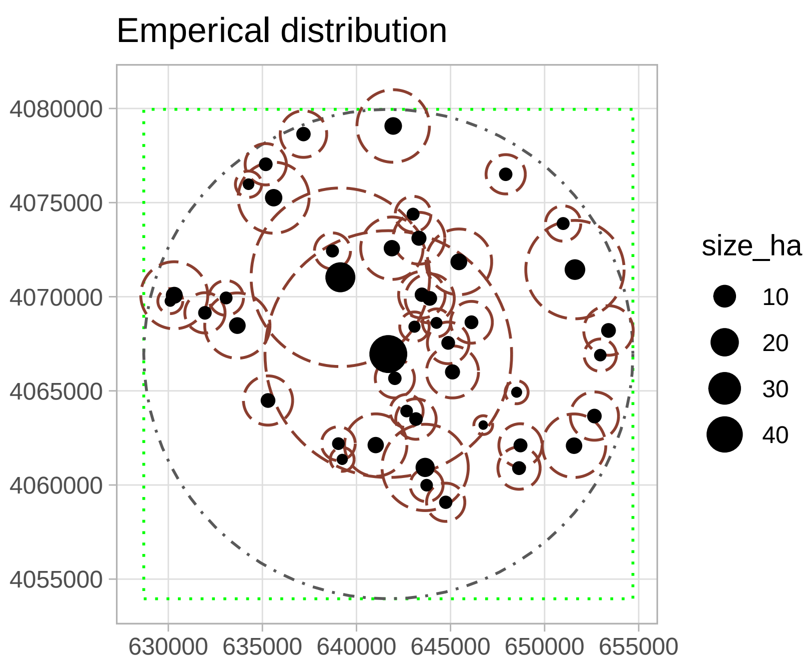
```
Simple feature collection with 2 features and 6 fields
Geometry type: POINT
Dimension:     XY
Bounding box:  xmin: 641692.6 ymin: 4064927 xmax: 648513.2 ymax: 4066955
Projected CRS: WGS 84 / UTM zone 37N
          id   size_ha                     geom  pop agr_zone_h agr_zone_m
1  TBS_1_0_0 45.000000 POINT (641692.6 4066955) 4500      13500   1.35e+08
2 TBS_11_0_0  0.393999 POINT (648513.2 4064927)   39        117   1.17e+06
  agr_radi_m
```

```
1       6555
2        610
```

```
# create buffers for AgrSA

agr_sa_emp = st_buffer(sites_emp, dist = sites_emp$agr_radi_m)
```

Plot AgrSA empirical

```
ggplot() +
  geom_sf(data = bbox, fill = NA, linetype = 21, color = "green") +
  geom_sf(data = survey, fill = NA, linetype = 22) +
  geom_sf(data = agr_sa_emp, fill = NA, linetype = 23, color = "coral4") +
  geom_sf(data = sites_IA, aes(size = size_ha)) +
  labs(
    title = "Emperical distribution"
  ) +
  coord_sf(datum = st_crs(sites)) +
  theme_light()
```

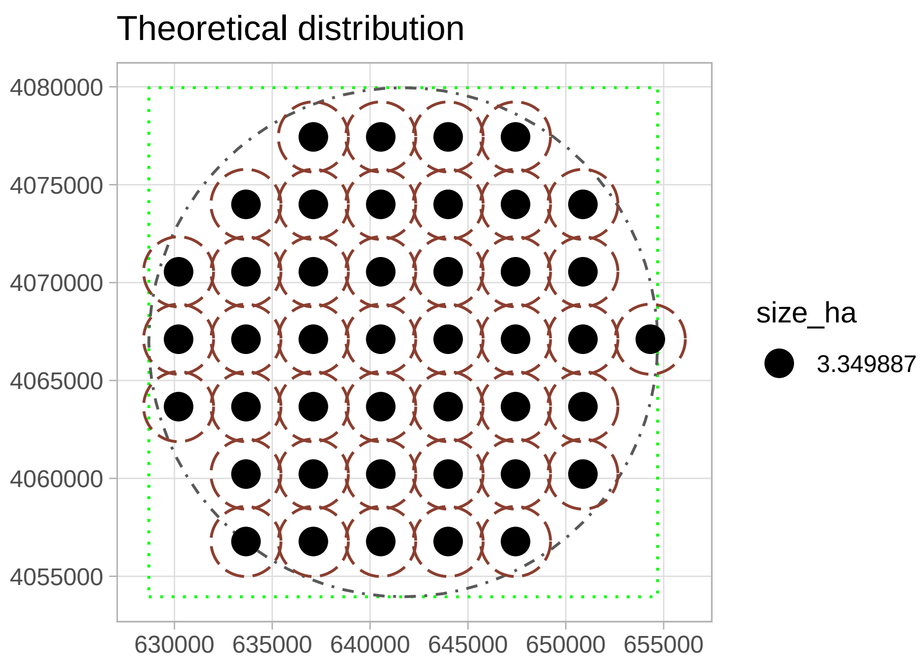


Calculate **Agricultural Sustaining Areas** for theoretical dataset

```r
# create a "regular" distribution of theoretical sites
# number of empirical sites
n = nrow(sites_emp)

# total area
region.area = sum(sites_emp$agr_zone_m)

#compute regular distribution
sites_theor = st_sample(survey,n, type = "regular", exact = TRUE, offset = c(0,0)) %>%
  st_as_sf()

# number of theoretical sites
k1 = nrow(sites_theor)

# compute area and radii for theoretical Agr SA
sites_theor = sites_theor %>%
  mutate(
    size_ha = sum(sites_emp$size_ha) / k1,
    agr_zone_m = region.area / k1,
    agr_radi_m = sqrt(region.area/(k1*pi))
  )

# create buffers for AgrSA
agr_sa_theor = st_buffer(sites_theor, dist = sites_theor$agr_radi_m)
```

Plot AgrSA theoretical

```r
ggplot() +
  geom_sf(data = bbox, fill = NA, linetype = 21, color = "green") +
  geom_sf(data = survey, fill = NA, linetype = 22) +
  geom_sf(data = agr_sa_theor, fill = NA, linetype = 23, color = "coral4") +
  geom_sf(data = sites_theor, aes(size = size_ha)) +
  labs(
    title = "Theoretical distribution"
  ) +
  coord_sf(datum = st_crs(sites)) +
  theme_light()
```



Coverage

$$I_{\text{coverage}} = \frac{\Sigma P_i}{P_r}$$

```
numerator.coverage = sum(sites_emp$agr_zone_m)

denominator.coverage = region.area

i.coverage = numerator.coverage / denominator.coverage

paste0("Index coverage is equal to: ", i.coverage)
```

```
[1] "Index coverage is equal to: 1"
```

always 1 when analyzing all sites within region / survey from one period

Distance

$$I_{\text{distance}} = \frac{\Sigma_i \Sigma_j d_{ij}/k}{\Sigma_i \Sigma_j \hat{d}_{ij}/k}$$

```
# empirical distance
numerator.distance = mean(st_distance(sites_emp))

# theoretical distance
denominator.distance= mean(st_distance(sites_theor))

i.distance = numerator.distance / denominator.distance

paste0("Index distance is equal to: ",i.distance)
```

```
[1] "Index distance is equal to: 0.87833602209736"
```

Overlap

$$I_{overlap} = \frac{P(\cup P_i)}{\Sigma P_i}$$

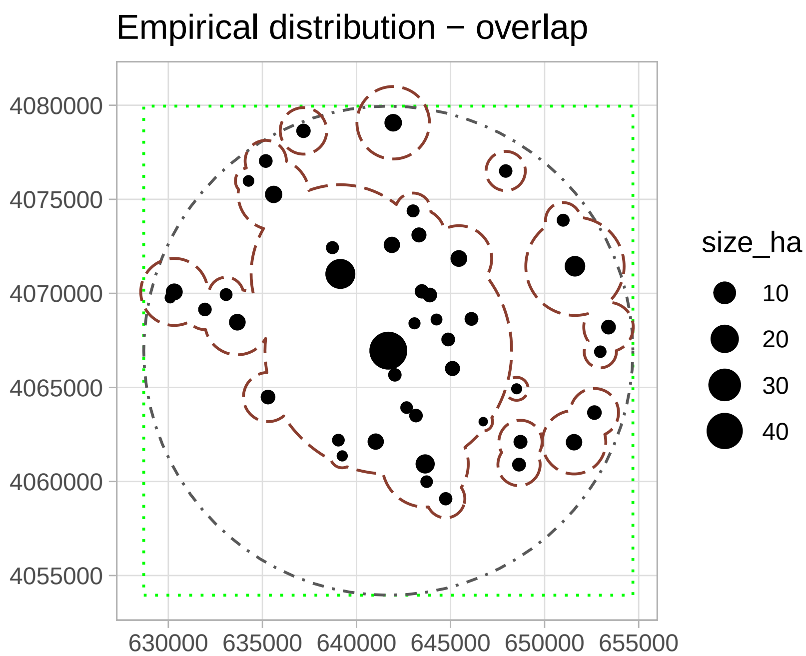
Compute union of overlapping agr areas

```
# create union of Agr SA
agr_sa_emp_union = st_union(agr_sa_emp)

# calculate the area of the overlapping areas
union_area = st_area(agr_sa_emp_union) # in m^2
```

Map

```
ggplot() +
  geom_sf(data = bbox, fill = NA, linetype = 21, color = "green") +
  geom_sf(data = survey, fill = NA, linetype = 22) +
  geom_sf(data = agr_sa_emp_union, fill = NA, linetype = 23, color = "coral4") +
  geom_sf(data = sites_emp, aes(size = size_ha)) +
  labs(
    title = "Empirical distribution - overlap"
  ) +
```

```r
  coord_sf(datum = st_crs(sites)) +
  theme_light()
```




```r
numerator.overlap = union_area

denominator.overlap = sum(sites_emp$agr_zone_m)

i.overlap = numerator.overlap / denominator.overlap

paste0("Index overlap  is equal to: ",i.overlap)
```

```
[1] "Index overlap  is equal to: 0.65025110873164"
```

SPAG

```r
i.spag = i.coverage * i.distance * i.overlap

paste0("SPAG indes  is equal to: ",i.spag)
```

```
[1] "SPAG indes  is equal to: 0.571138972207746"
```

Scalar value between 0 (agglomeration) and 1 (regular distribution).