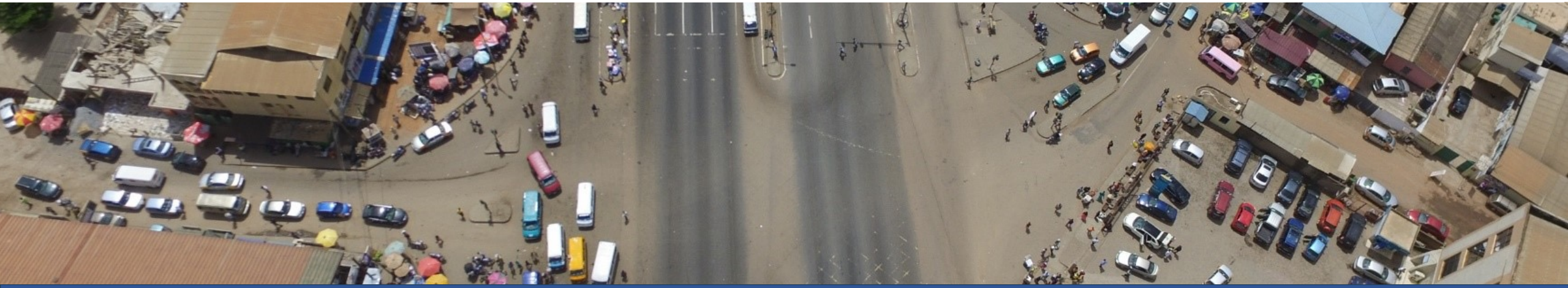
Global Engagement

UNIVERSITY OF GHANA



UCL-UoG International Workshop

Day 1: Introduction to Geoprocessing in RStudio

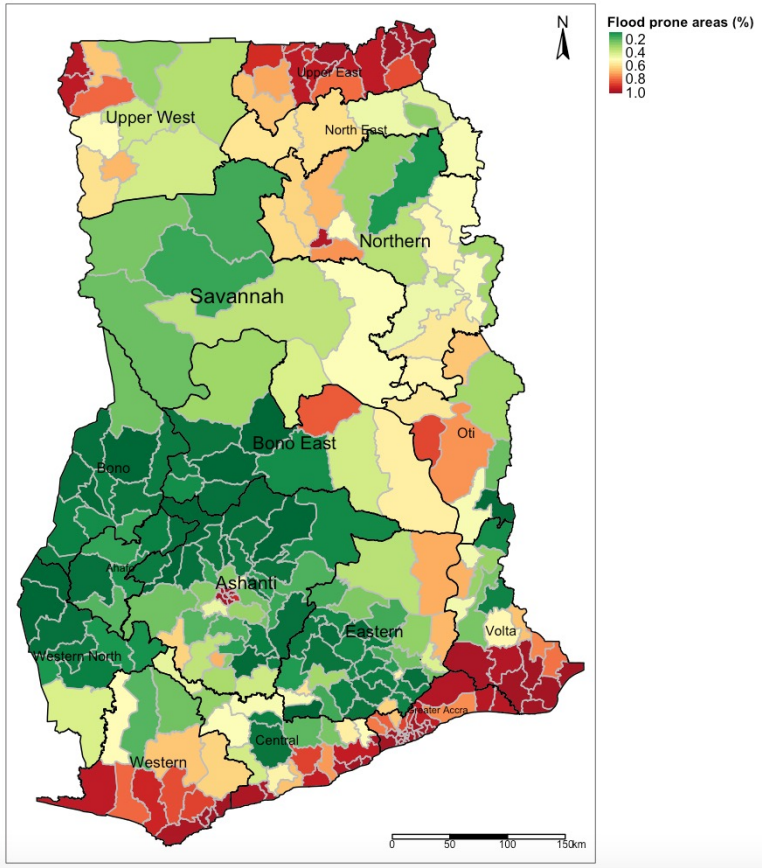
Team: Dr. Anwar Musah, Prof. Luiza Campos, Dr. Mumuni Abu, Dr. Stephen Law

What will we learn?

What will we learn?

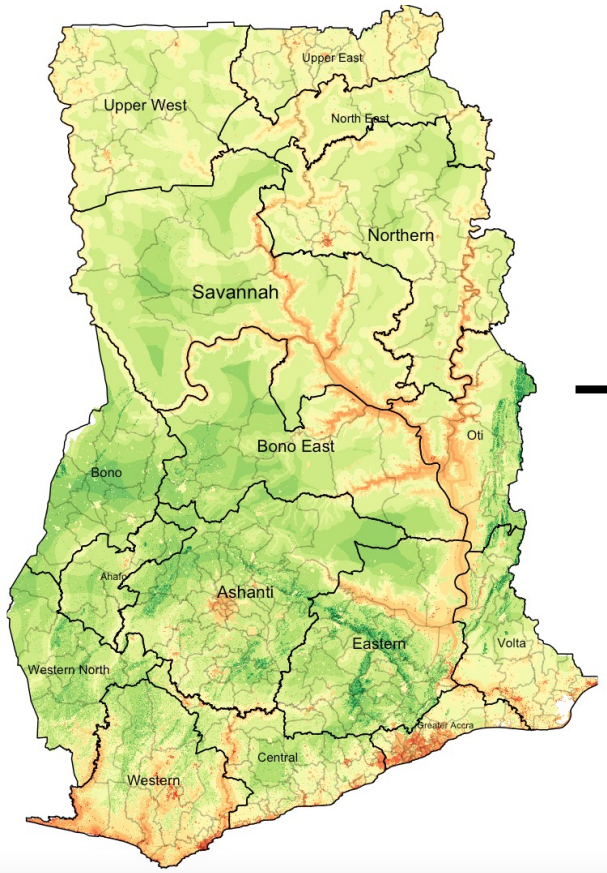
- To introduce you to etiquettes of RStudio and its programming environment
- You will be introduced to the various types of spatial data
- For the day 1 practical – you will be shown how to merge non-spatial attribute data with that this spatial. The focus will be on “vector data”
- You will be shown how to use the “tmap” and “sf” packages to perform various geoprocessing to visualise areal data from a shapefile. This particular dataset will focus on flood hazards across Ghana.

Day 1 (Vector)

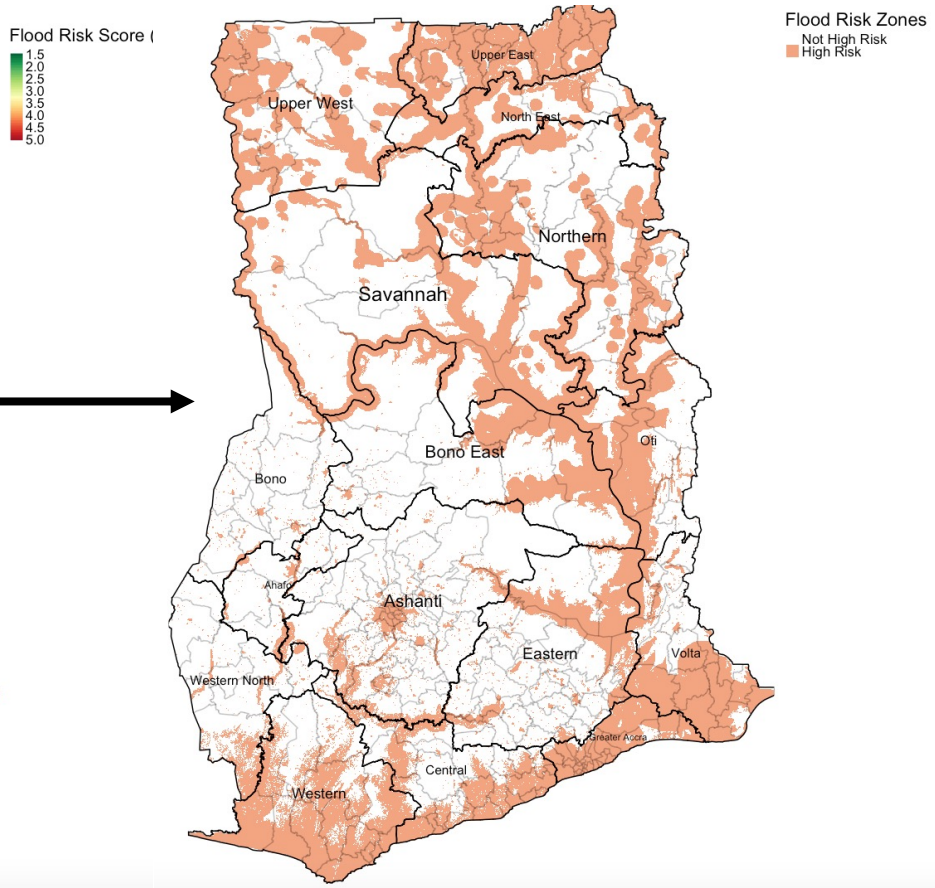


Mapping burden of surface affected by floods in districts in Ghana

Day 2 (Raster)

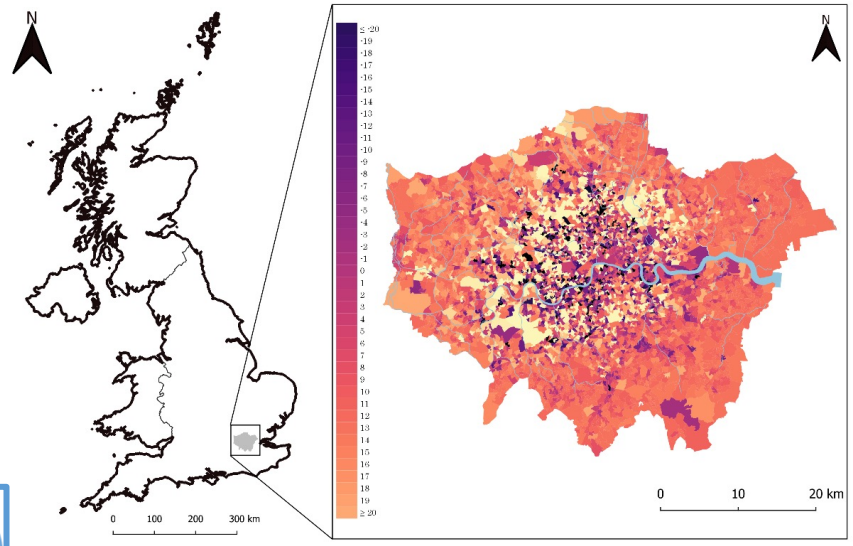


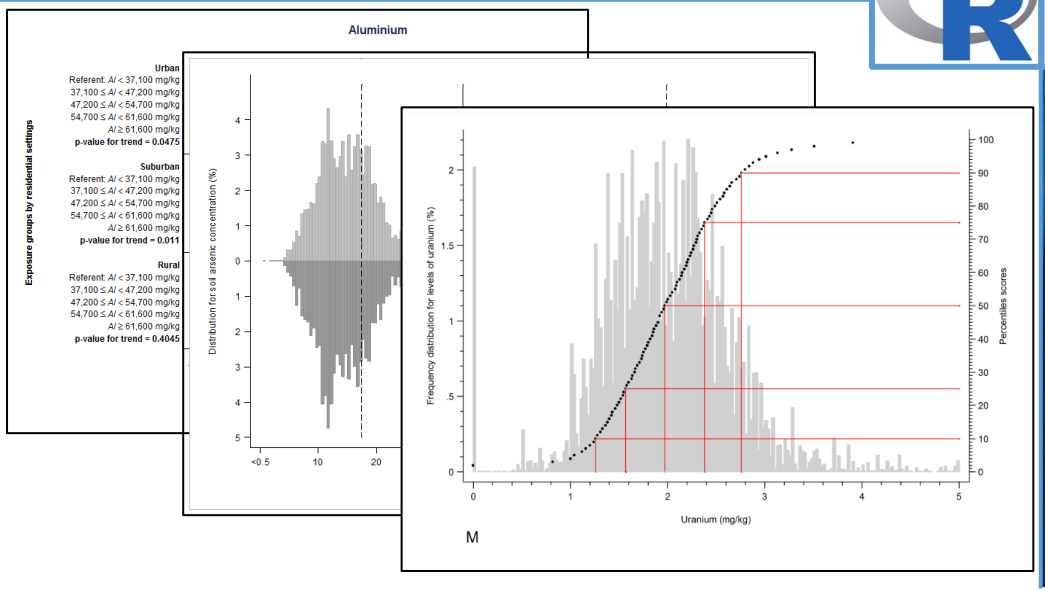
Compute risk score for pixels across Ghana based on a set of environmental variables with decisions

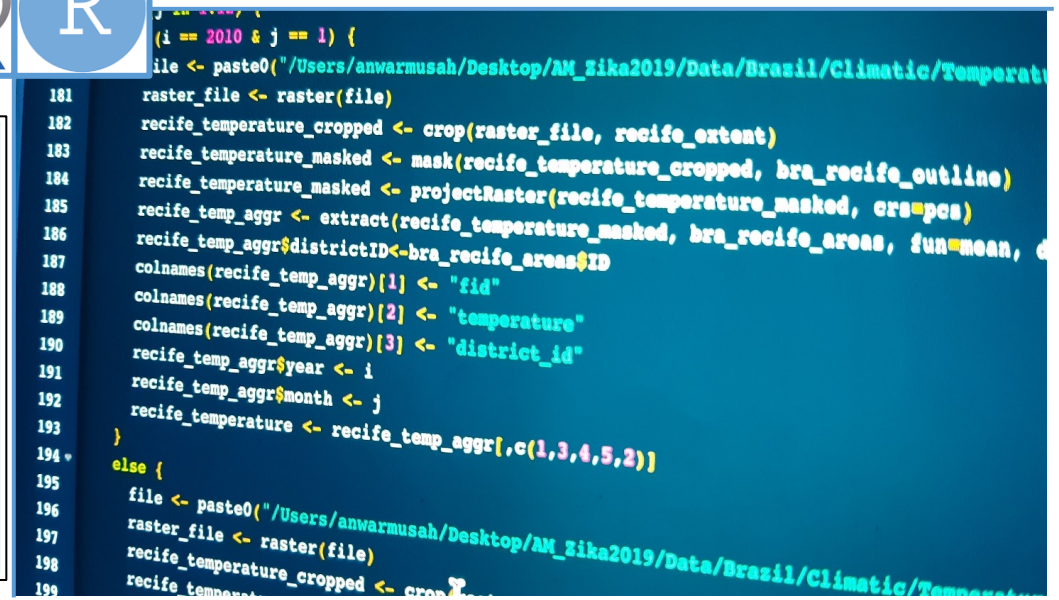


Reclassify risk scores based on a threshold (> 4, high risk and above). Zone the areas in Ghana

What is RStudio?







```
(i == 2010 & j == 1) {
ile <- paste0("/Users/anwarmusah/Desktop/AM_Zika2019/Data/Brazil/Climatic/Temperat
  raster_file <- raster(file)
  recife_temperature_cropped <- crop(raster_file, recife_extent)
  recife_temperature_masked <- mask(recife_temperature_cropped, bra_recife_outline)
  recife_temperature_masked <- projectRaster(recife_temperature_masked, crs=pcs)
  recife_temp_aggr <- extract(recife_temperature_masked, bra_recife_areas, fun=mean,
  recife_temp_aggr$districtID<-bra_recife_areas$ID
  colnames(recife_temp_aggr)[1] <- "fid"
  colnames(recife_temp_aggr)[2] <- "temperature"
  colnames(recife_temp_aggr)[3] <- "district_id"
  recife_temp_aggr$year <- i
  recife_temp_aggr$month <- j
  recife_temperature <- recife_temp_aggr[,c(1,3,4,5,2)]
}
else {
  file <- paste0("/Users/anwarmusah/Desktop/AM_Zika2019/Data/Brazil/Climatic/Temperature
  raster_file <- raster(file)
  recife_temperature_cropped <- crop
```


30


GDAL


OGC®
Making location count.


Arc
ESRI
GIS


ArcGIS® Pro


OSGeo
Project


CARTO


PROJ.4


gv
SIG


OPEN JUMP
Jump Unified Mapping Platform


R Studio®

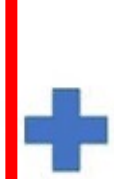

30


GDAL


OGC®
Making location count.


Arc
ESRI
GIS


ArcGIS® Pro




OSGeo
Project


CARTO


gv
SIG


PROJ.4


OPEN JUMP
Jump Unified Mapping Platform


R Studio®

R (Standard)

RStudio (Best)

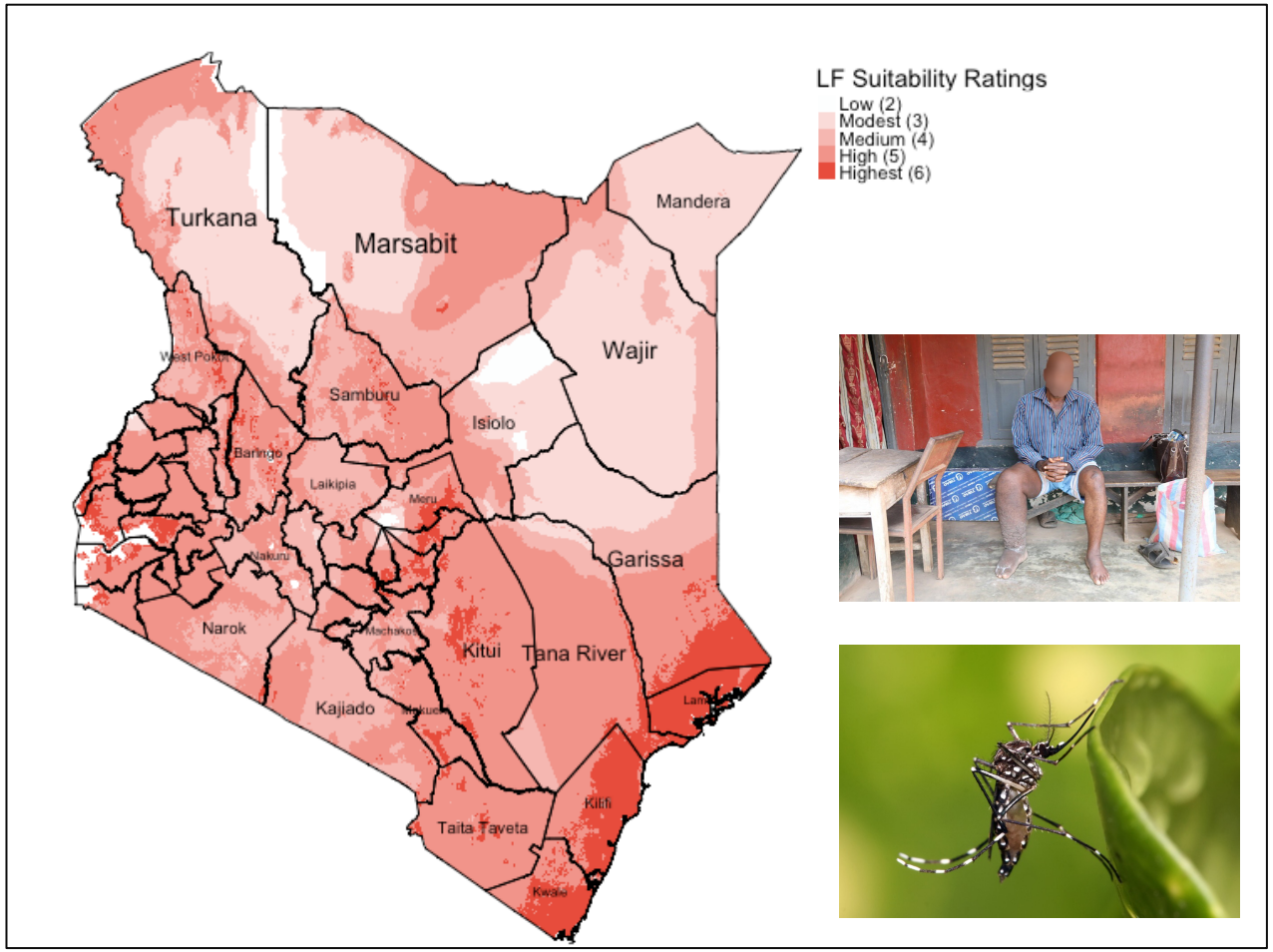
There are two version of the software: 1.) R, and 2.) RStudio; The second is much preferred as its straightforward and intuitive.

Why are we teaching RStudio?

1. Flexible and provides access to powerful packages for analysis

2. Impressive graphs, visualizations and maps

3. Excellent statistical capabilities too



Example: Map generated in R to illustrate areas that are environmentally suitable for the spread of neglected tropical disease called 'Lymphatic Filariasis (LF)' in Kenya.

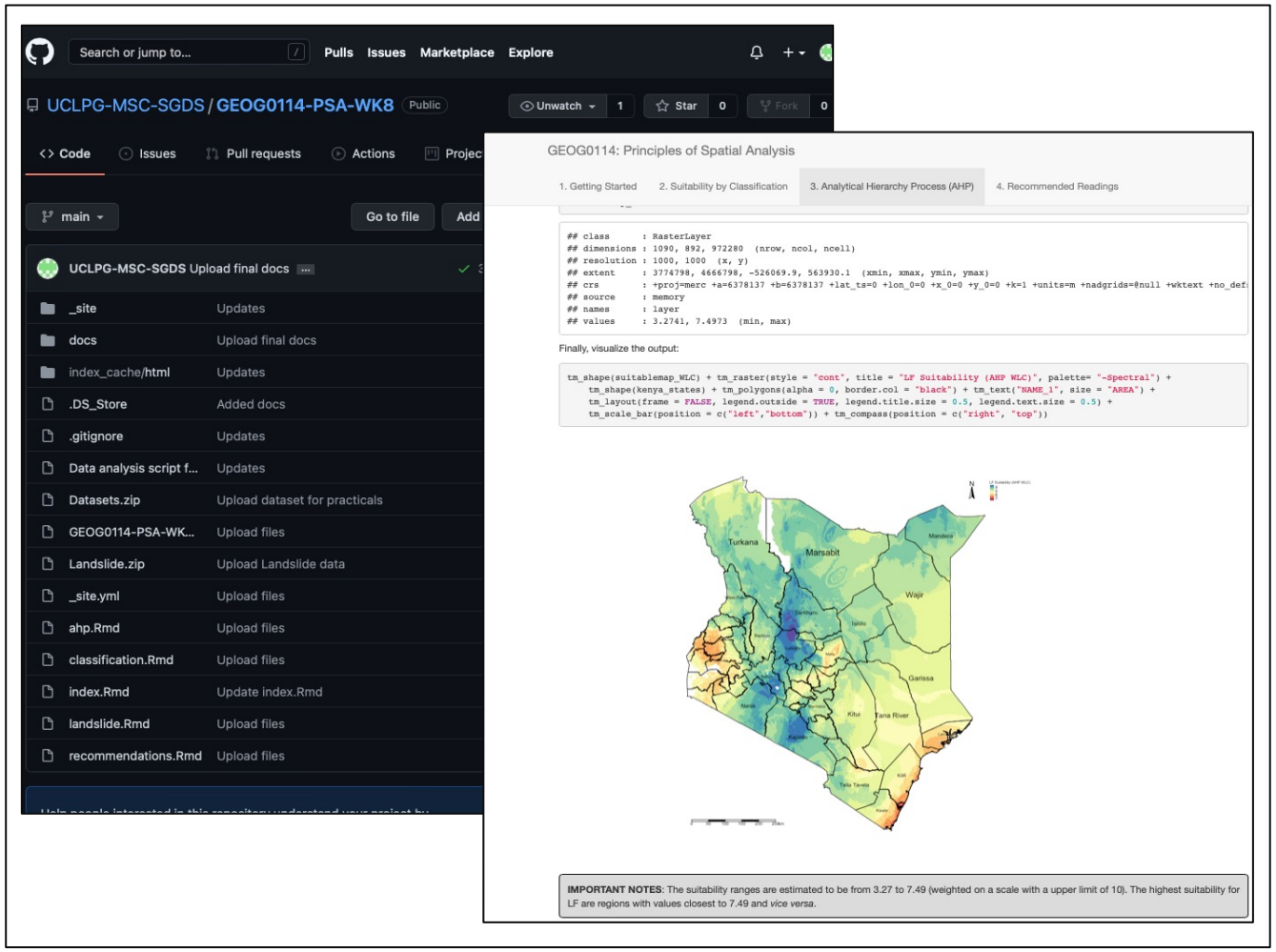
Sources:
1. Global Atlas for Helminths Infection (http://www.thiswormyworld.org)
2. ESPEN (https://espen.afro.who.int)

… and why learn how to code in RStudio?

1. **Efficiency**
   - Automated tasks and data managing
   - Can recycle & reuse code scripts for new projects

2. **Fosters good scientific practice**
   - Transparency and replication (AKA reproducible research)
   - Creates log so anyone can follow in your footstep (i.e., github, gitlab etc.,)

You can literally pull-off some really creative stuff like generating websites, accessing tools via APIs etc.



Example: Working in RStudio and synchronising it with GitHub to not only use as a cloud back-up, but to generate a website through RStudio and GitHub for teaching MSc Students.

Sources:
1. GitHub (https://github.com)

What is Vector Spatial Data & its Features?

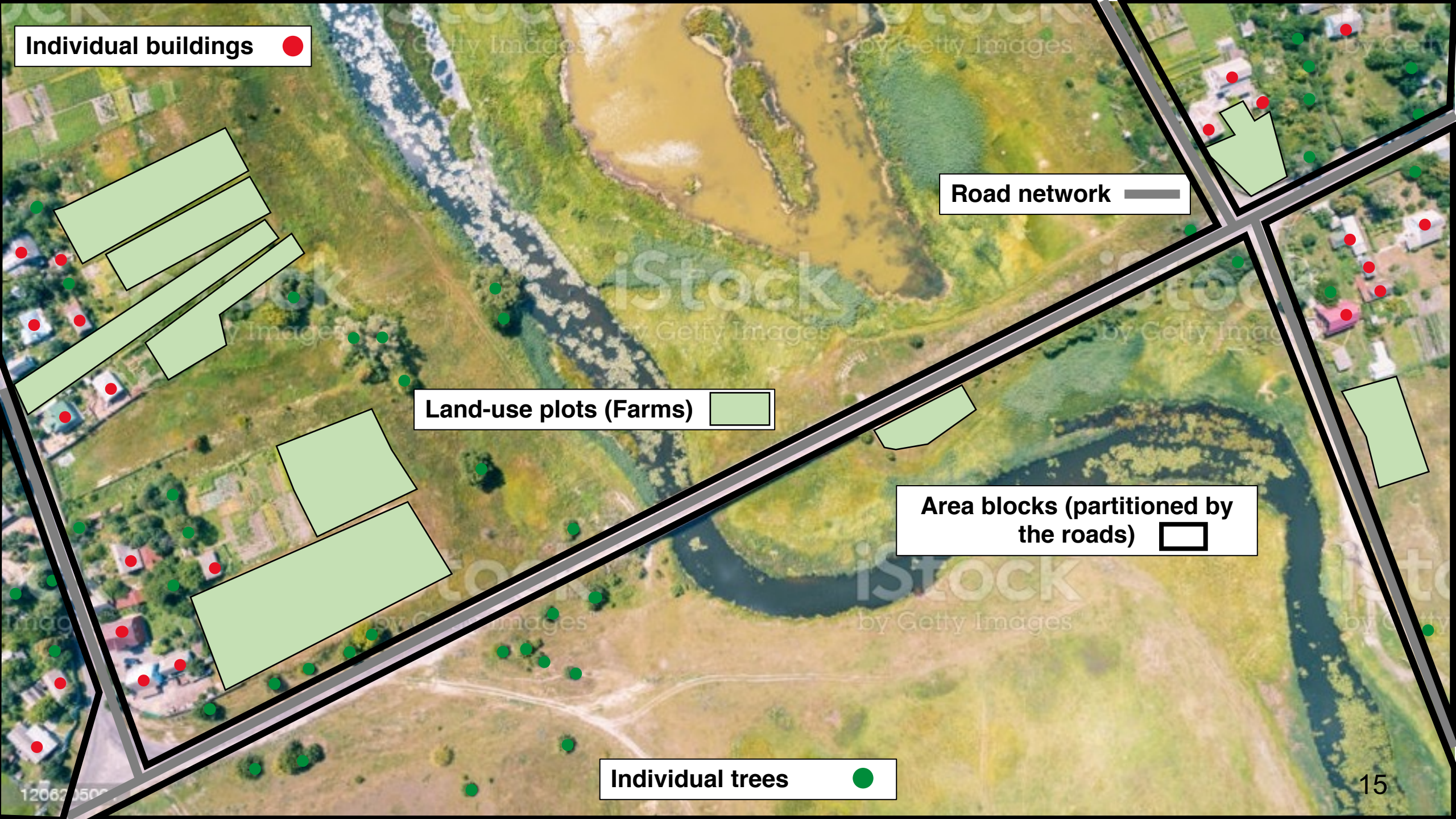
Suppose we want to map the following from this landscape:

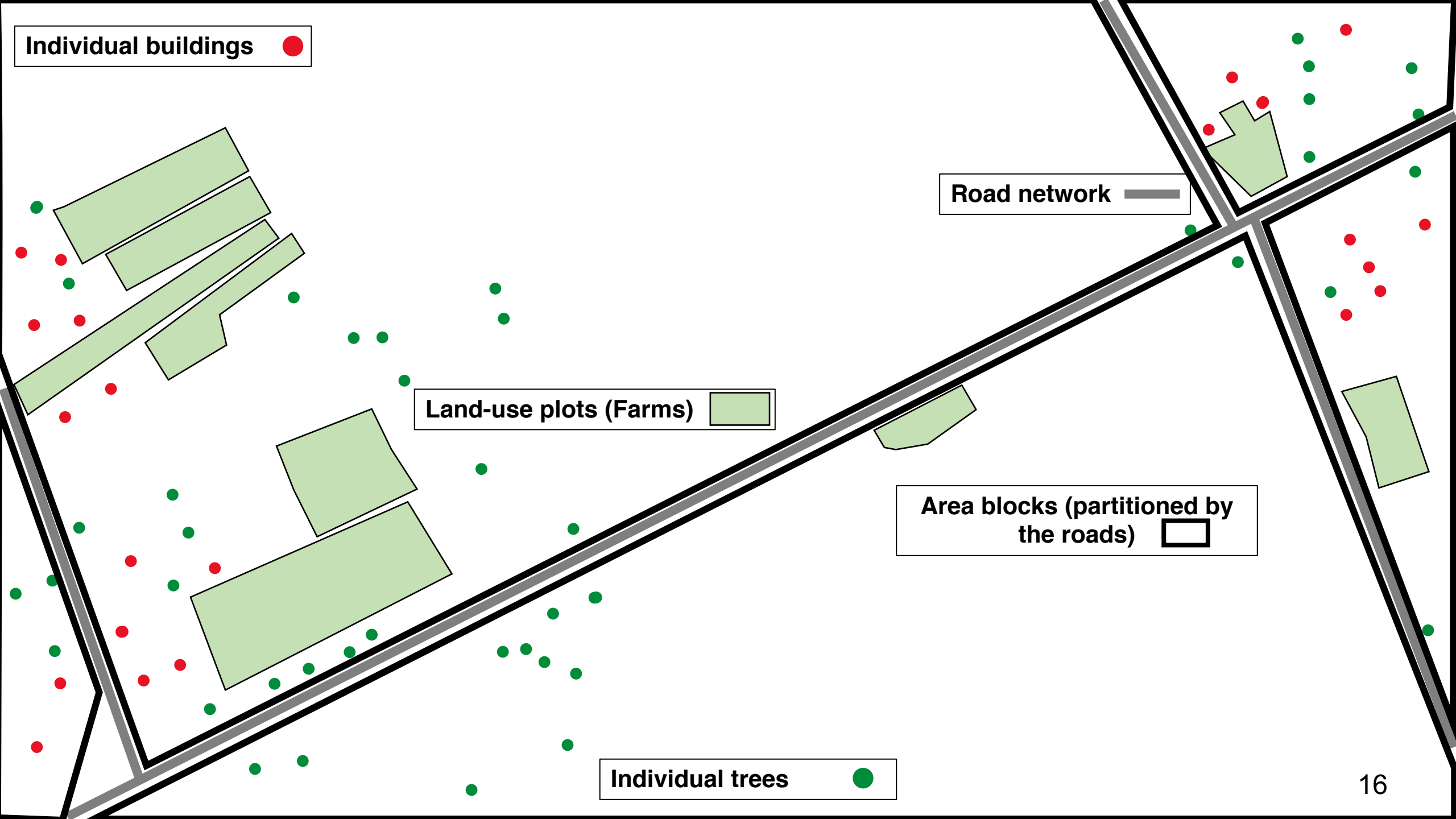
1. Physical objects:

- Location of buildings
- Farm plots
- Locations of trees
- Road network
- Block areas (divided by the road)

2. Levels of soil moisture across the landscape


Individual buildings
Road network
Land-use plots (Farm)
Area blocks (partitioned by the roads)
Individual trees


Individual buildings
Road network
Land-use plots (Farms)
Area blocks (partitioned by the roads)
Individual trees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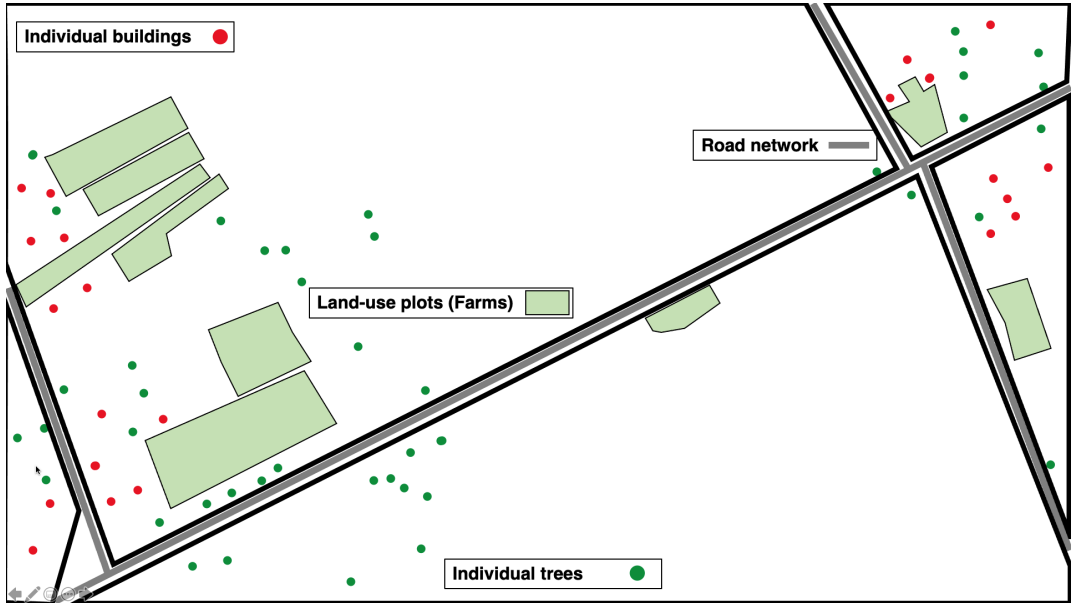
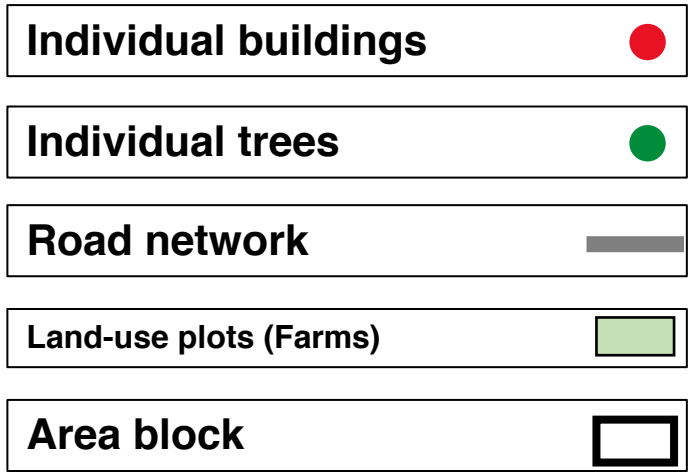
Individual trees





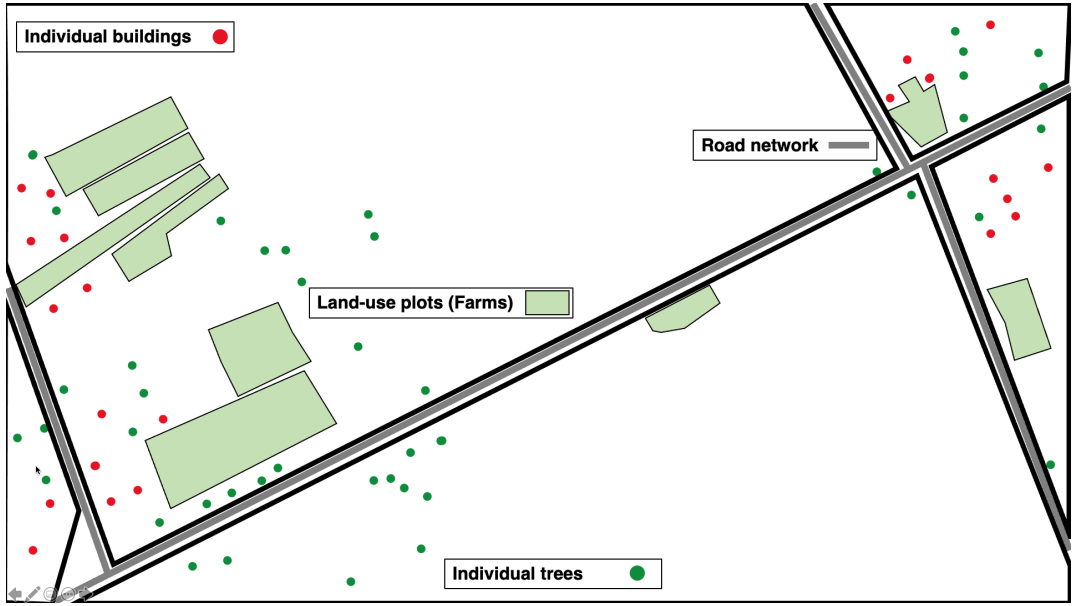
The above objects listed are called "**Features**". A feature can be described according to its characteristics which is termed an "**Attribute**" in GIS. The attribute of a feature can be a **numeric** or **text** observation.

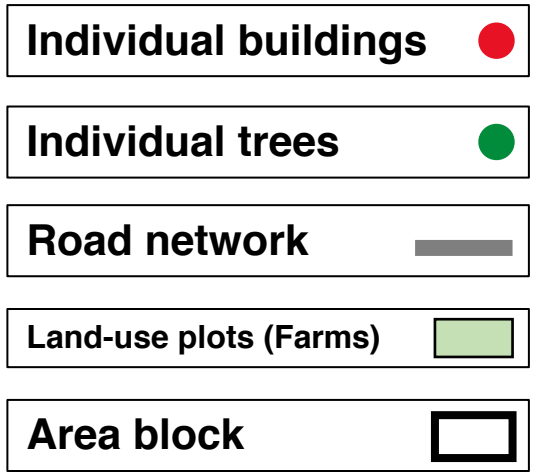
For example:

- A building is a **point feature** on this map, the number of people living a building is a **numeric attribute** describing this **feature**. Type of building (i.e., Victorian or modern) is a **text attribute**

- The road network is a **polyline feature**, the length (or distance (m)) of the road is a **numeric attribute** describing the road

- Land-use plot is a **polygon (or area) feature**, the type of land-use (i.e., farming) is the **text attribute** describing what that polygon is etc.

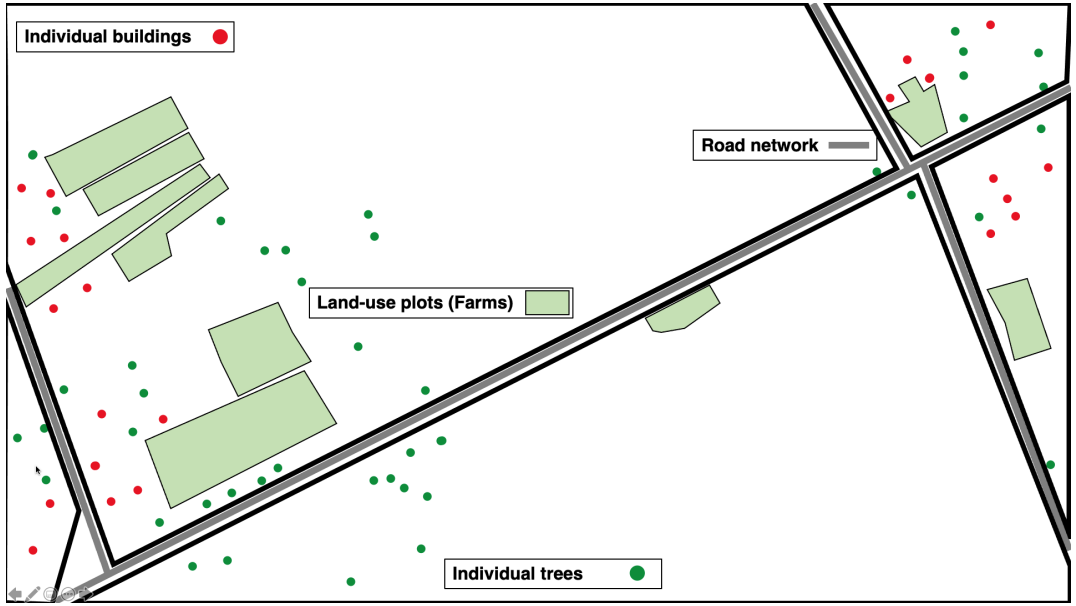


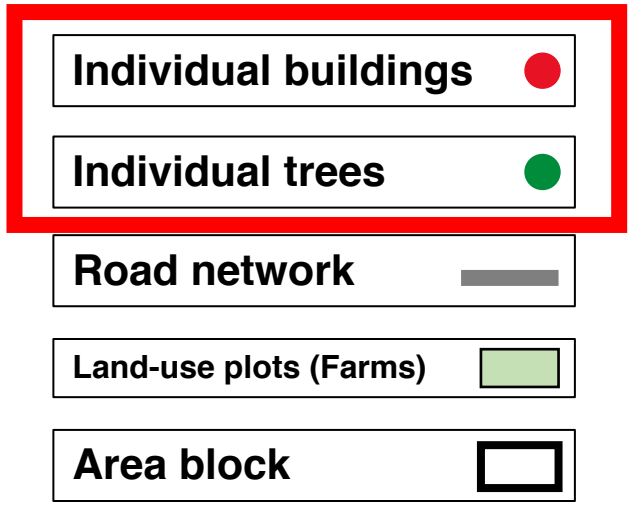


Now, the above objects are typically **Discrete** features, and therefore classed a **Vector Data**

There are three main types of **Vector Data**:

1. **Point vector**
2. **Polylines or Line vector**
3. **Polygon vector**





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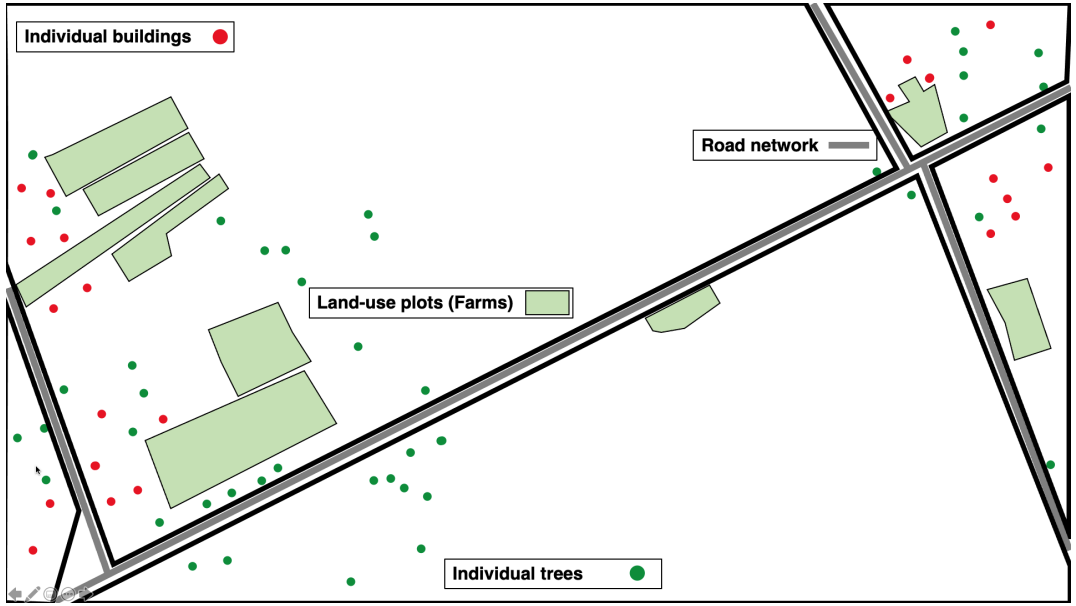
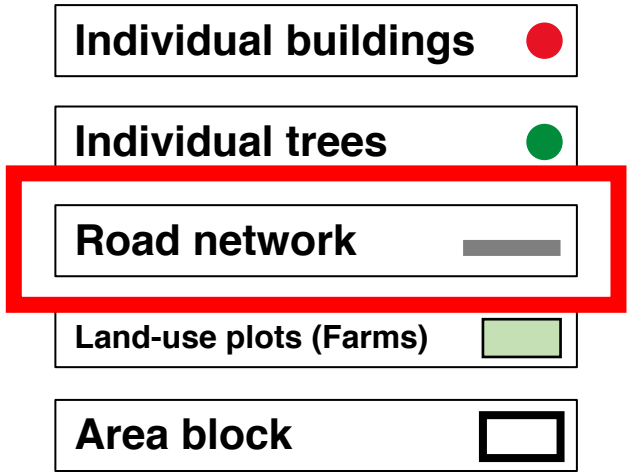
Characteristics of a point vector

- X, Y location characterize as a coordinate
- Has no area
- Has no length
- This applies to discrete features of sample points
- Its geometry consists of a single **node** or **vertex**





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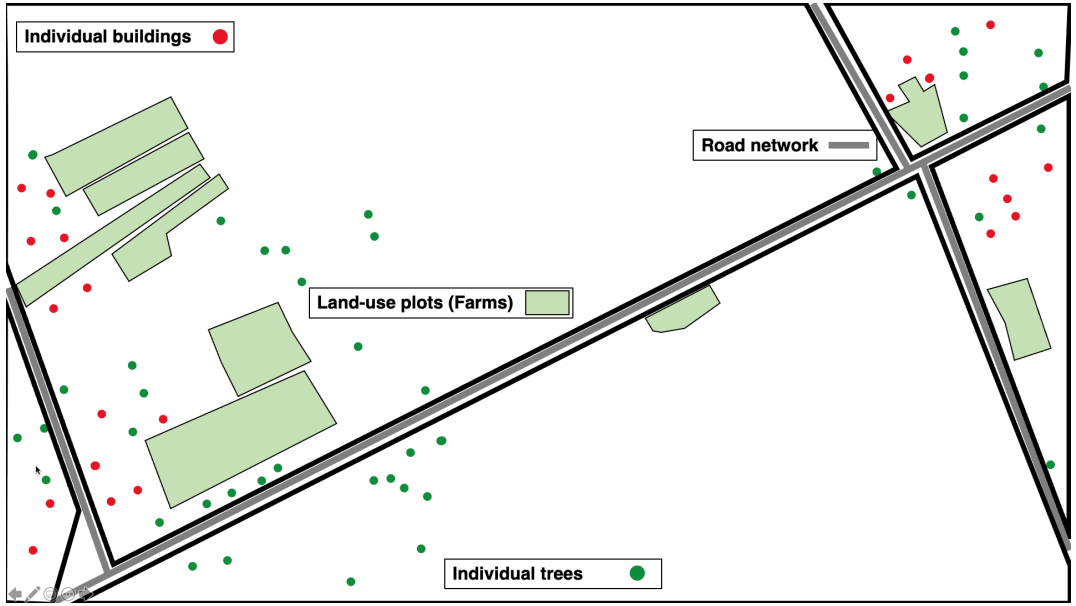
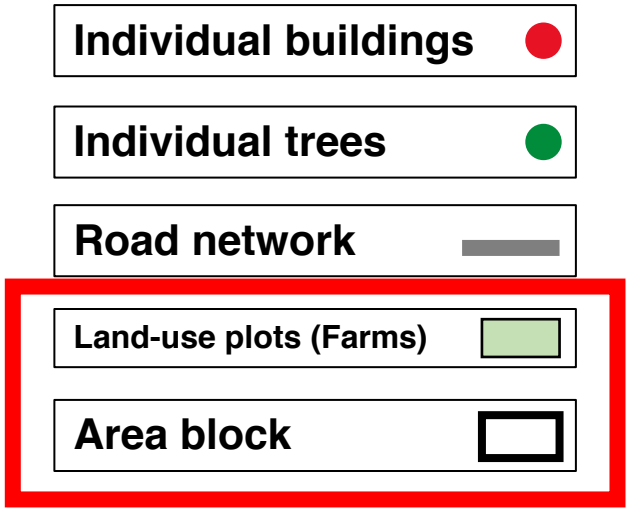
Characteristics of a polyline or line vector

- These are a series of X, Y points characterize by coordinates to form a line
- Has no area
- They have a length
- They have a direction (important for visualizing rivers steams & roads)
- Connectivity (it connecting to other lines segments in the network)
- This applies to features without an area but with a length – roads, rivers, railway tracks or migration flows between two or more locations.
- Its geometry consists of **2 nodes** (i.e., beginning and end of point of line) & can have more than one **vertex** (i.e., point(s) that connect different lines together)
- It is never enclosed





Now, the above objects are typically **Discrete** features, and therefore classed a **Vector Data**

There are three main types of **Vector Data**:

1. **Point vector**
2. **Polylines or Line vector**
3. **Polygon vector**

Characteristics of a polygon vector

- These are a series of X, Y points characterize by coordinates to form an enclosed region
- It has an area
- It has no length but rather a perimeter instead
- This applies to features with enclosed regions – e.g., postcode areas, area of residential premise, counties (other administrative boundaries) etc.
- Polygons have **three vertices** or more each connecting sequentially where the first vertex connects with the last vertex.

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RIPS

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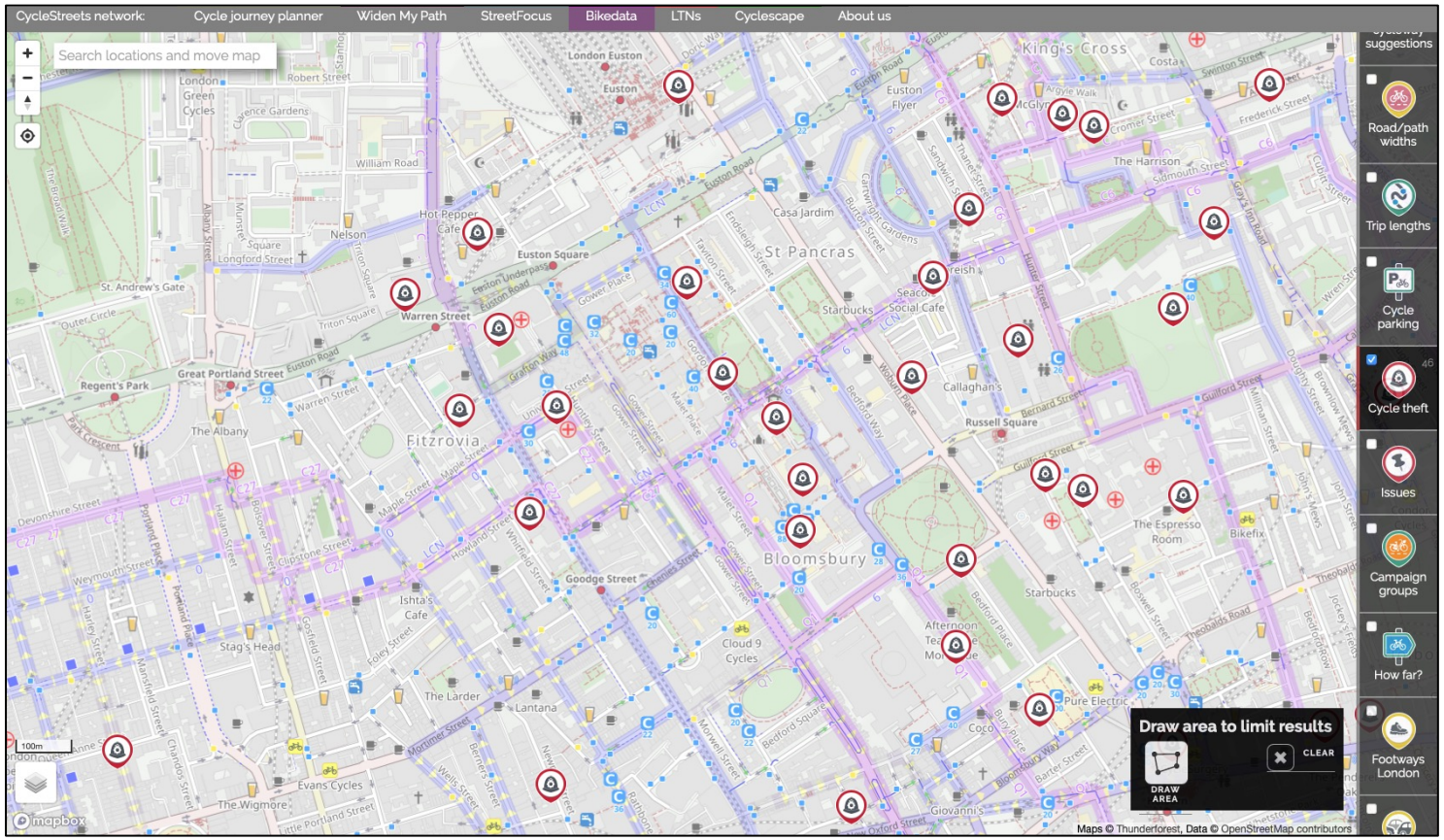
Point Pattern Data (PPD)



Represents point locations of bicycle thefts in Central London area
Source: BikeData.CycleStreets network https://bikedata.cyclestreets.net/

Key Characteristics

The main interest is the occurrences of an event at a points (or points). These events occur at “random” at any given geographic space and time.

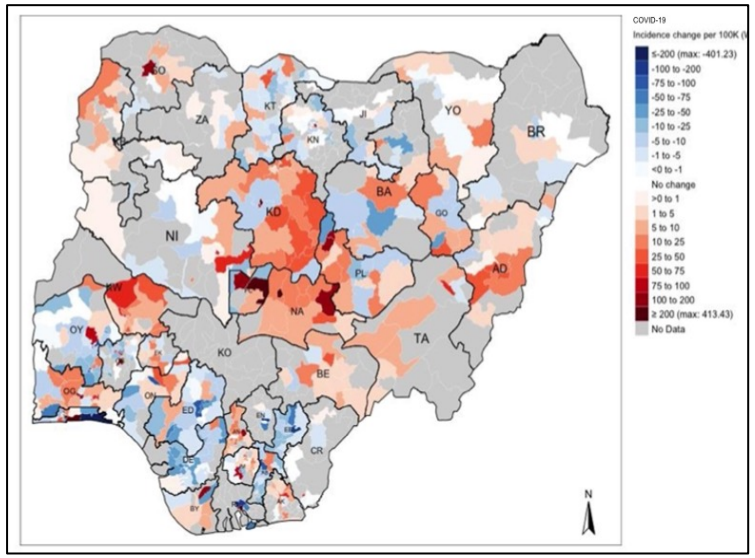
Examples of PPDs events (or outcomes):

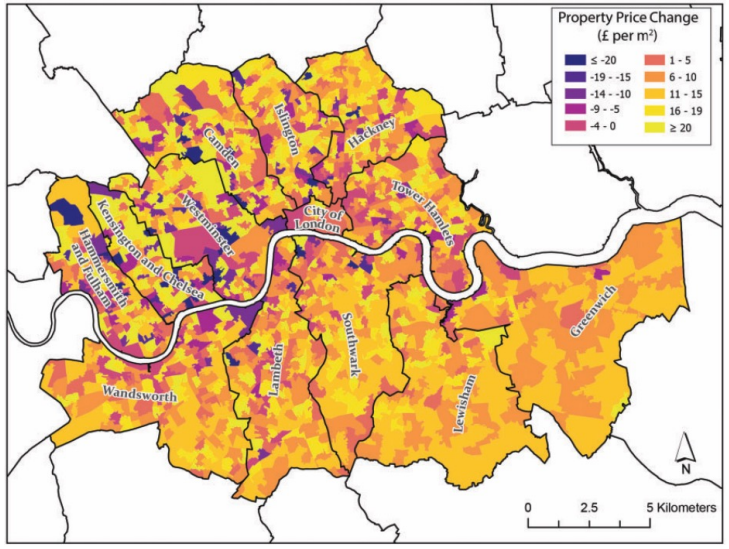
- Point locations of burglaries
- Riots
- Locations of car collisions etc.,
- Locations of where an adult tree needs to be replanted

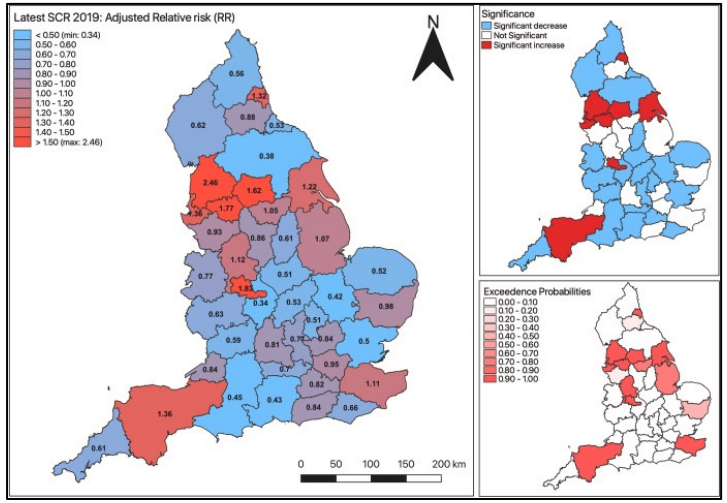
Some PPDs events may carry additional information that may describe the occurrence of an observed event (or outcome):

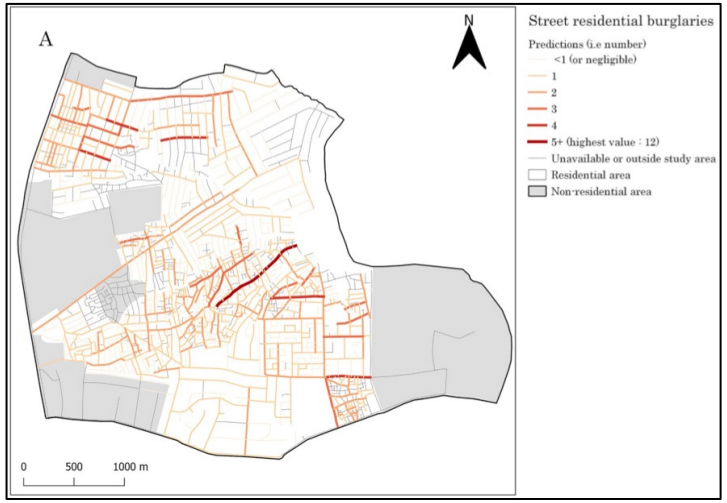
- Burglary: Type of premise that was burgled, time of day the burglary occurred etc.,
- Car collision: type of road, weather condition etc.

Aggregated Data









Key Characteristics

The main interest the quantity of interest defined for line segments, areas, or regions.

Events (or outcomes) that are aggregated measures to areas:

- Prevalence of a disease in areas
- Population density in a county
- Regional unemployment rates
- Risk of an outcome

Sources:
Musah, A., *et al.* (2020): https://doi.org/10.1016/j.apgeog.2019.102126
Todd, J., *et al.* (2021): https://doi.org/10.1177/23998083211001836
Li, L., *et al.* (2022): https://doi.org/10.1016/j.apgeog.2022.102718
Elimian, K., *et al*. (2022): http://dx.doi.org/10.1136/bmjopen-2022-063703

Non-spatial context & data structure:

	ATTRIBUTE			
	Variable 1	**Variable 2**	$\cdots$	**Variable n**
Entity 1	$attribute_{11}$	$attribute_{12}$	$\cdots$	$attribute_{1n}$
Entity 2	$attribute_{21}$	$attribute_{22}$	$\cdots$	$attribute_{2n}$
$\vdots$	$\vdots$	$\vdots$	$\ddots$	$\vdots$
Entity m	$attribute_{m1}$	$attribute_{m2}$	$\cdots$	$attribute_{mn}$

To apply some spatial analysis to data – you must have some variable that defines the entity's geographic location. This can be **GPS coordinates**, **spatially referenced geometries** of an area

NOTES: It is not enough to have the just the name of the area(s). It must be some geometric entry!

- Attributes that defines an entity's location are typically excluded from the analysis
- The conventional statistical methods, that assumes independence, are used for analyzing such dataset
- Results churned from this dataset are completely independent from "**spatial arrangement**" of the entities.

Spatial context & data structure [1]:

	Geographical Coordinate		ATTRIBUTE			
	X	Y	Variable 1	Variable 2	⋯	Variable n
Entity 1	X_1	Y_1	$attribute_{11}$	$attribute_{12}$	⋯	$attribute_{1n}$
Entity 2	X_2	Y_2	$attribute_{21}$	$attribute_{22}$	⋯	$attribute_{2n}$
⋮	⋮	⋮	⋮	⋮	⋱	⋮
Entity m	X_m	Y_m	$attribute_{m1}$	$attribute_{m2}$	⋯	$attribute_{mn}$

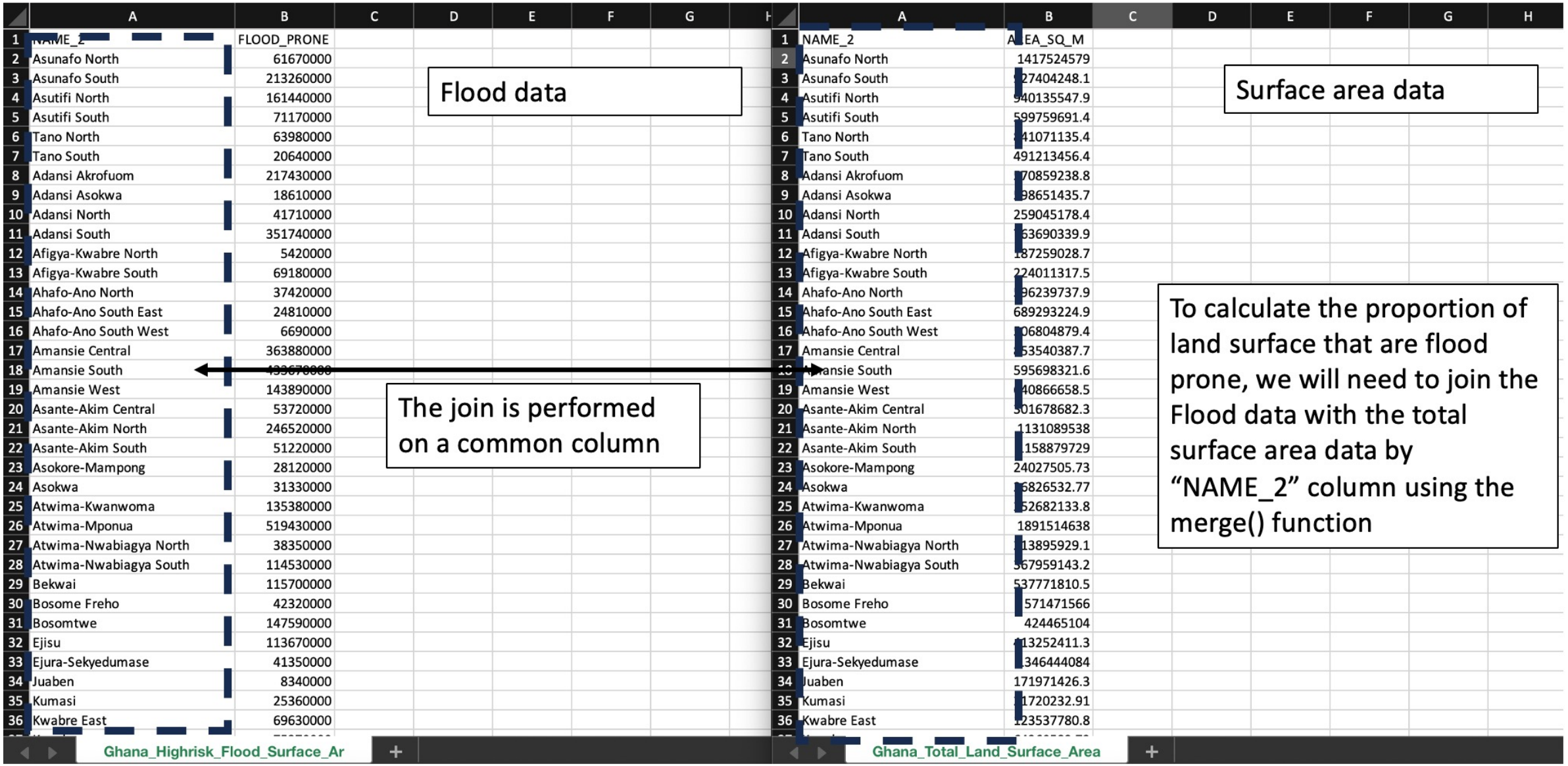
In this example, what defines the entity's geographic location are **X, Y GPS coordinates.**

Definition of an entity's location are not limited to coordinates, you can have spatially reference areas with their associated boundaries with geometries.

This instance illustrates an example of geostatistical data.

- Attributes that defines an entity's location are typically explicitly incorporated into analysis
- Spatial statistical methods, that assumes dependence, are used for analyzing such geographically referenced dataset
- Results churned from this dataset are completely dependent from "**spatial arrangement**" of the entities.

Spatial context & data structure [2]:



	A	B
1	NAME_2	FLOOD_PRONE
2	Asunafo North	61670000
3	Asunafo South	213260000
4	Asutifi North	161440000
5	Asutifi South	71170000
6	Tano North	63980000
7	Tano South	20640000
8	Adansi Akrofuom	217430000
9	Adansi Asokwa	18610000
10	Adansi North	41710000
11	Adansi South	351740000
12	Afigya-Kwabre North	5420000
13	Afigya-Kwabre South	69180000
14	Ahafo-Ano North	37420000
15	Ahafo-Ano South East	24810000
16	Ahafo-Ano South West	6690000
17	Amansie Central	363880000
18	Amansie South	[illegible]
19	Amansie West	143890000
20	Asante-Akim Central	53720000
21	Asante-Akim North	246520000
22	Asante-Akim South	51220000
23	Asokore-Mampong	28120000
24	Asokwa	31330000
25	Atwima-Kwanwoma	135380000
26	Atwima-Mponua	519430000
27	Atwima-Nwabiagya North	38350000
28	Atwima-Nwabiagya South	114530000
29	Bekwai	115700000
30	Bosome Freho	42320000
31	Bosomtwe	147590000
32	Ejisu	113670000
33	Ejura-Sekyedumase	41350000
34	Juaben	8340000
35	Kumasi	25360000
36	Kwabre East	69630000

Ghana_Highrisk_Flood_Surface_Ar

Flood data

The join is performed on a common column

	A	B
1	NAME_2	AREA_SQ_M
2	Asunafo North	1417524579
3	Asunafo South	927404248.1
4	Asutifi North	940135547.9
5	Asutifi South	599759691.4
6	Tano North	941071135.4
7	Tano South	491213456.4
8	Adansi Akrofuom	870859238.8
9	Adansi Asokwa	398651435.7
10	Adansi North	259045178.4
11	Adansi South	863690339.9
12	Afigya-Kwabre North	187259028.7
13	Afigya-Kwabre South	224011317.5
14	Ahafo-Ano North	896239737.9
15	Ahafo-Ano South East	689293224.9
16	Ahafo-Ano South West	206804879.4
17	Amansie Central	863540387.7
18	Amansie South	595698321.6
19	Amansie West	640866658.5
20	Asante-Akim Central	501678682.3
21	Asante-Akim North	1131089538
22	Asante-Akim South	1158879729
23	Asokore-Mampong	24027505.73
24	Asokwa	26826532.77
25	Atwima-Kwanwoma	352682133.8
26	Atwima-Mponua	1891514638
27	Atwima-Nwabiagya North	913895929.1
28	Atwima-Nwabiagya South	967959143.2
29	Bekwai	537771810.5
30	Bosome Freho	1571471566
31	Bosomtwe	424465104
32	Ejisu	913252411.3
33	Ejura-Sekyedumase	1346444084
34	Juaben	171971426.3
35	Kumasi	1720232.91
36	Kwabre East	123537780.8

Ghana_Total_Land_Surface_Area

Surface area data

To calculate the proportion of land surface that are flood prone, we will need to join the Flood data with the total surface area data by “NAME_2” column using the merge() function

Workflow of the online handbook

Format and learning flow [1]

To generate `bmi` into our data frame, we would need to access the `height` (m) and `weight` (kg) columns using the `$` from the data frame its stored to, and apply the above formula as a code to generate the new `bmi` column:

```r
# Create 'bmi' in the data frame i.e.,'dataset' and calculate 'bmi'
# using the $weight and $height
dataset$bmi <- dataset$weight/((dataset$height)^2)
# View the data frame 'dataset' and you will see the new bmi variable inside
View(dataset)
```

You can overwrite the `height` (m) column to change its units into centimeters by multiplying it to 100; equally, the `weight` (kg) column can be overwritten and converted from units of kilograms to grams by multiplying it to 1000.

```r
# using $height and *100
dataset$height <- dataset$height*100
# using $weight and *100
dataset$weight <- dataset$weight*1000
# use View() the data frame 'dataset' and you will see the updated variables
View(dataset)
```

There will always be a video to explain the necessary theory of the statistical method, as well as an explanation of the code

Format and learning flow [2]

To generate `bmi` into our data frame, we would need to access the `height` (m) and `weight` (kg) columns using the `$` from the data frame its stored to, and apply the above formula as a code to generate the new `bmi` column:

```
# Create 'bmi' in the data frame i.e.,'dataset' and calculate 'bmi'
# using the $weight and $height
dataset$bmi <- dataset$weight/((dataset$height)^2)
# View the data frame 'dataset' and you will see the new bmi variable inside
View(dataset)
```

You can overwrite the `height` (m) column to change its units into centimeters by multiplying it to 100; equally, the `weight` (kg) column can be overwritten and converted from units of kilograms to grams by multiplying it to 1000.

```
# using $height and *100
dataset$height <- dataset$height*100
# using $weight and *100
dataset$weight <- dataset$weight*1000
# use View() the data frame 'dataset' and you will see the updated variables
View(dataset)
```

There will always be a text to explain the necessary what the code is also doing, and steps for coding – so here, you will have to read through the text.

Format and learning flow [3]

To generate `bmi` into our data frame, we would need to access the `height` (m) and `weight` (kg) columns using the `$` from the data frame its stored to, and apply the above formula as a code to generate the new `bmi` column:

```
# Create 'bmi' in the data frame i.e.,'dataset' and calculate 'bmi'
# using the $weight and $height
dataset$bmi <- dataset$weight/((dataset$height)^2)
# View the data frame 'dataset' and you will see the new bmi variable inside
View(dataset)
```

Comment

Actual code

You can overwrite the `height` (m) column to change its units into centimeters by multiplying it to 100; equally, the `weight` (kg) column can be overwritten and converted from units of kilograms to grams by multiplying it to 1000.

```
# using $height and *100
dataset$height <- dataset$height*100
# using $weight and *100
dataset$weight <- dataset$weight*1000
# use View() the data frame 'dataset' and you will see the updated variables
View(dataset)
```

There will always be code chunks for you to replicate and study in your own RStudio.

The code chunks will be annotated with a # (hash tag) with a comment to give context. So, this is not actual code

The real code is the code chuck with no # (hash tag) at the beginning.

Let’s begin the walkthrough