Including environmental covariates into movement analysis

Animal movement course 8-12 september 2025

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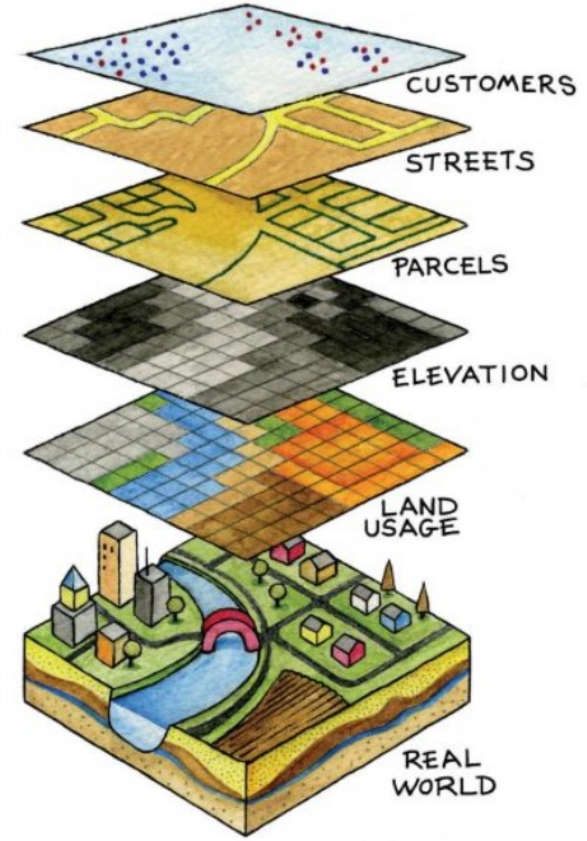
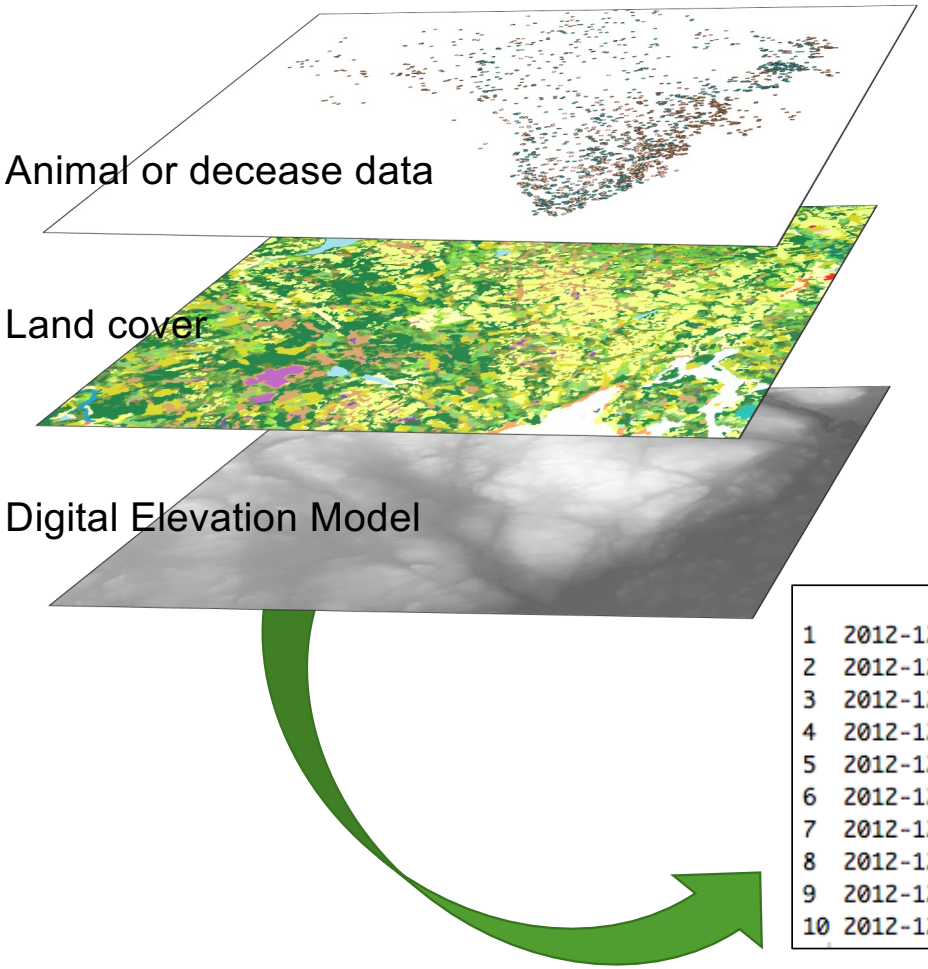
Environmental data



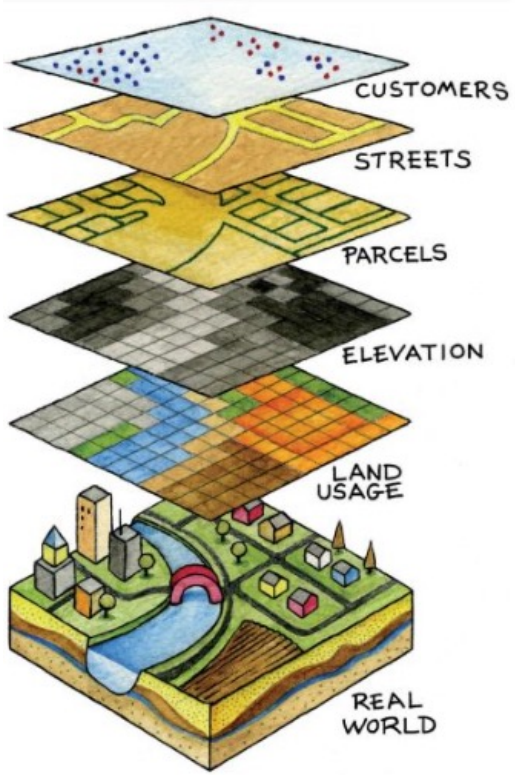
Shin et al. 2017

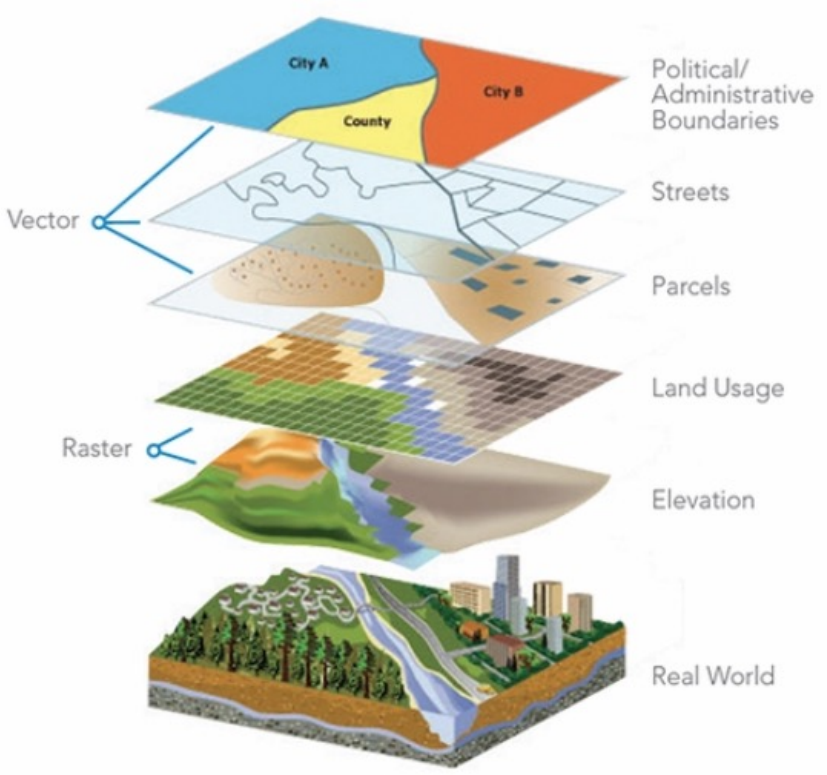


	dateC	dem	vegUp3	x	y
1	2012-12-17 15:56:00	107.58	Coni	712980.9	7056619
2	2012-12-17 15:56:00	114.05	ConiLich	715988.9	7056523
3	2012-12-17 15:56:00	125.93	Coni	712833.8	7057787
4	2012-12-17 15:56:00	160.20	Mix	709749.4	7057632
5	2012-12-17 15:56:00	206.94	ConiLich	710753.2	7054354
6	2012-12-17 15:56:00	69.33	ConiLich	714136.2	7048449
7	2012-12-17 15:56:00	185.51	Clear	707445.0	7056881
8	2012-12-17 15:56:00	160.73	Coni	713993.5	7054894
9	2012-12-17 15:56:00	139.23	ConiLich	714479.9	7051756
10	2012-12-17 15:56:00	130.50	Mire	715542.8	7056836

Environmental data – Types of data

- Vector
- Raster





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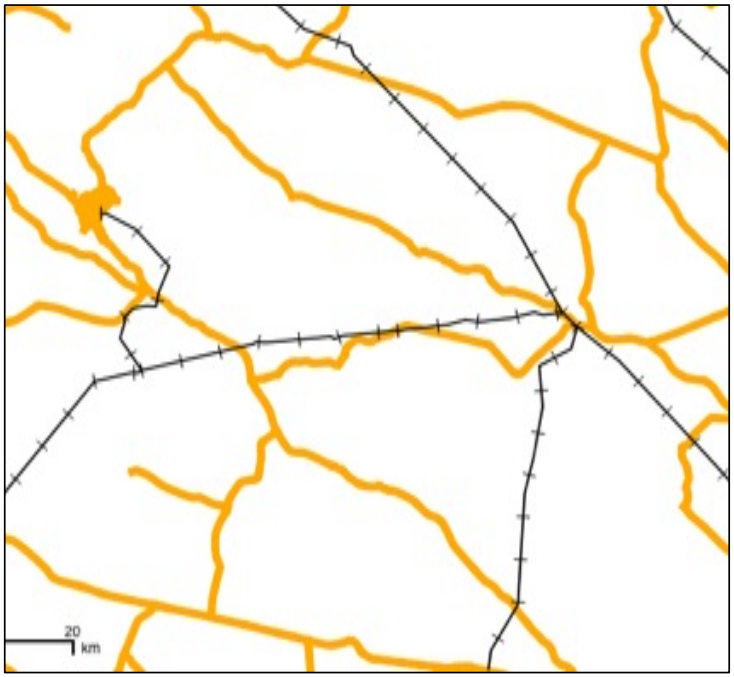
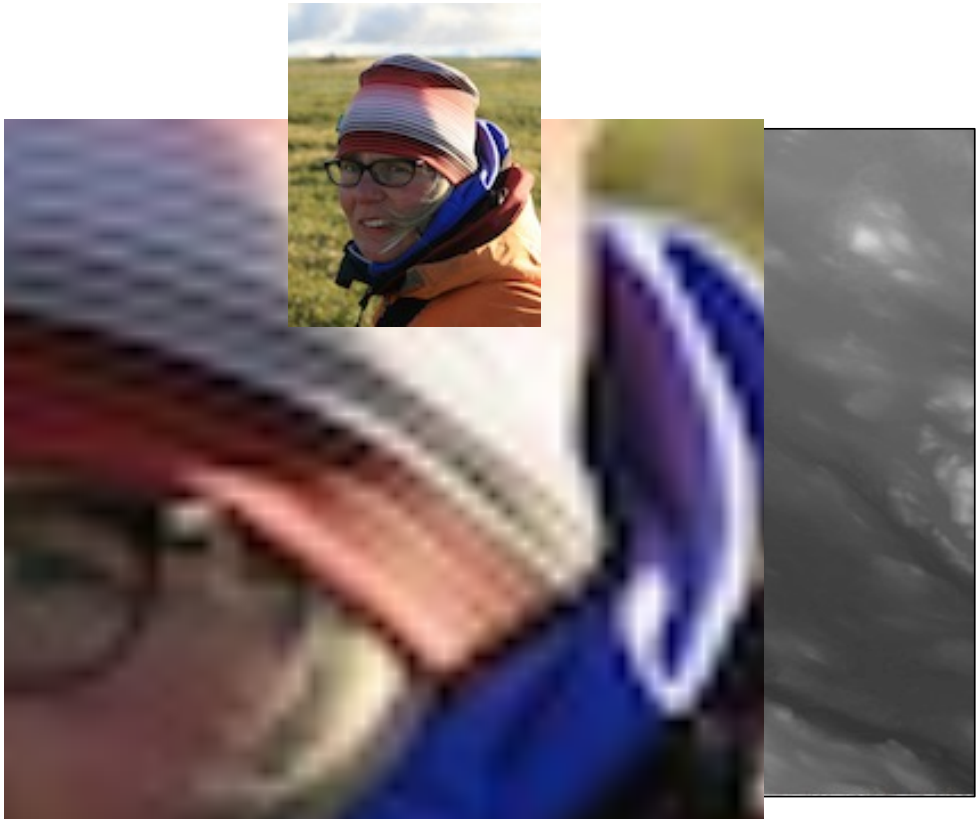
Campbell & Shin (2012), ESRI (2019)

Example data class

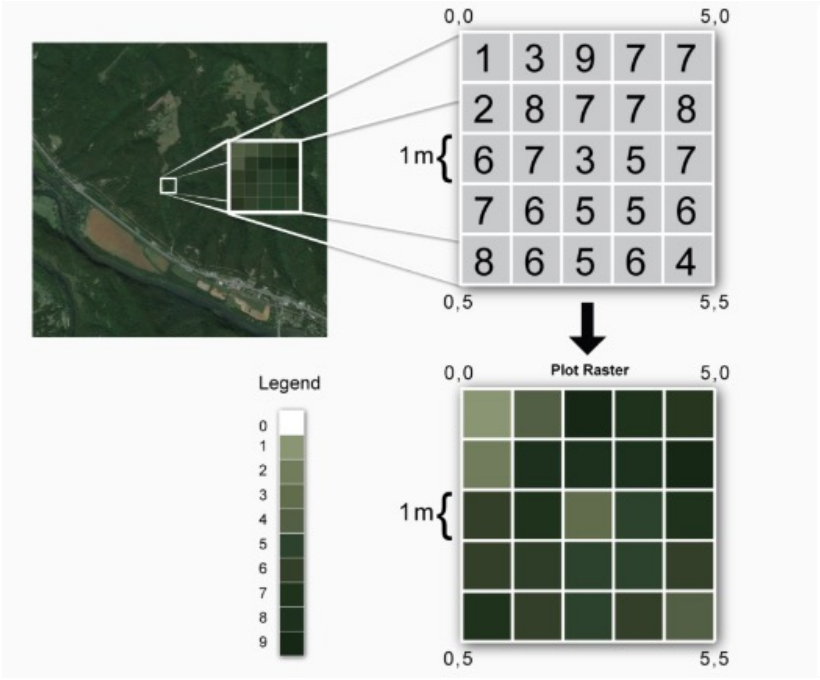


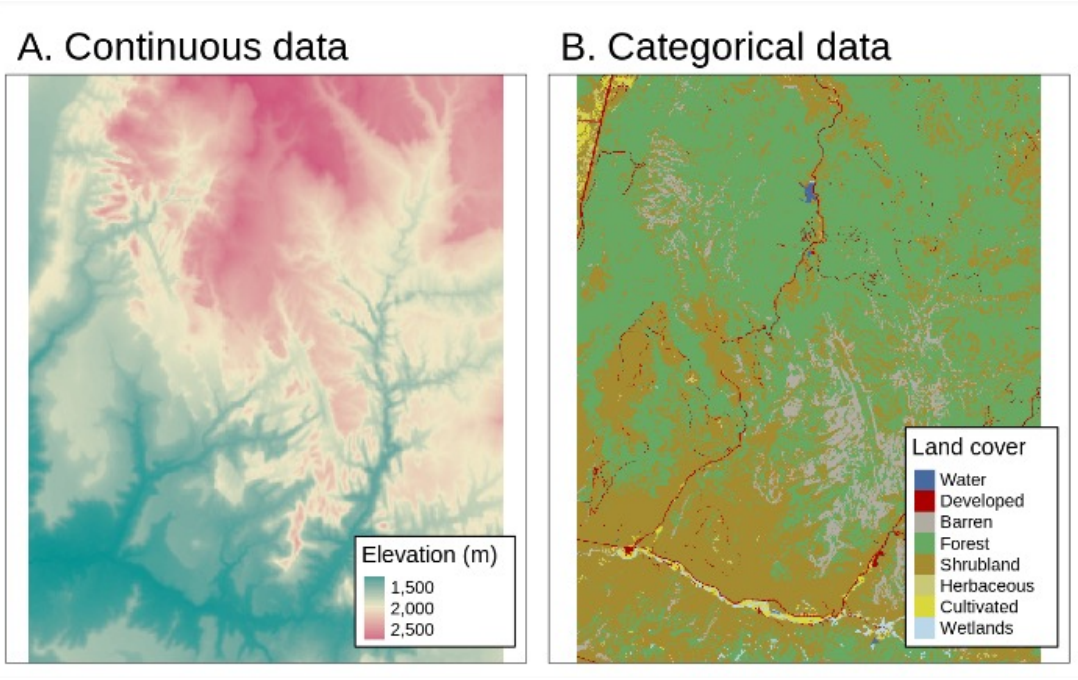


Environmental data – Types of data

- Raster

Matrix with values – continuous or





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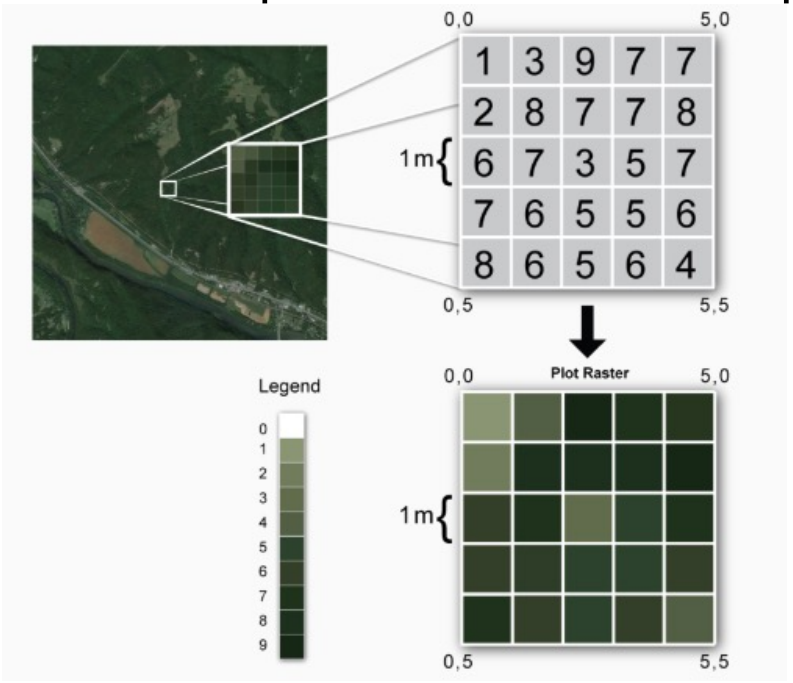
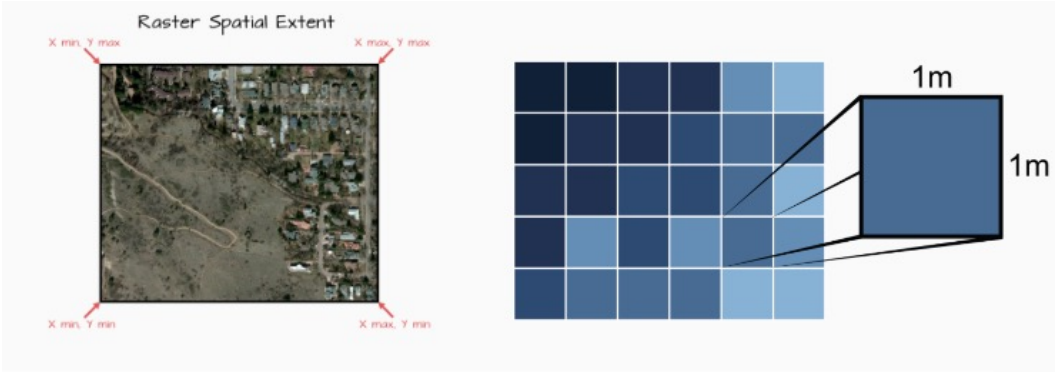
National Ecological Observatory Network (NEON), Lovelace et al. (2020)

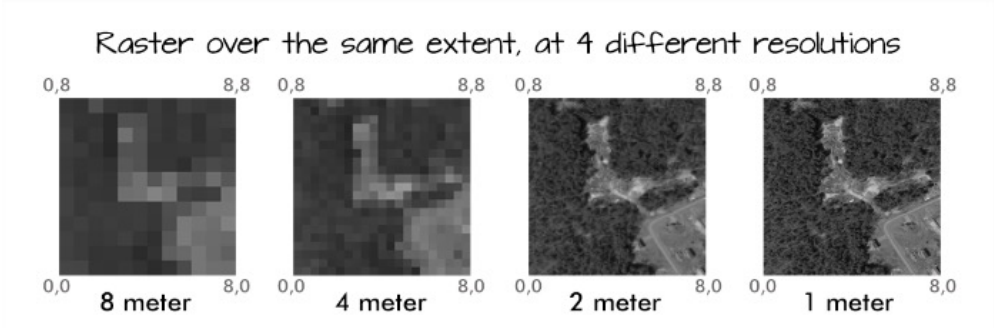
Environmental data – Types of data

- Raster

Properties – extent and spatial resolution







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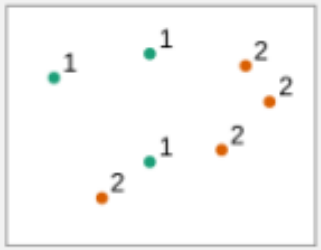
National Ecological Observatory Network (NEON)

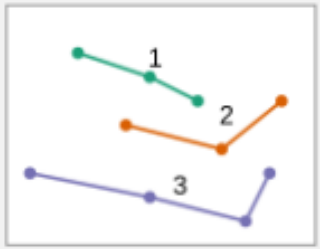
Environmental data – Types of data

- Vector
  - Shapefile
  - Geopackage



Example attributes for point data

ID	name	has	evergreen
1	Broadleaf	Leaves	FALSE
2	Conifer	Needles	TRUE



Example attributes for line data

ID	name	lanes	cycling
1	Road A	4	FALSE
2	Road B	3	TRUE
3	Road C	2	TRUE

Example attributes for polygon data

ID	name	population	touristic
1	Country A	1000	FALSE
2	Country B	500	TRUE

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Structure data class

- Vector data
  - one row per feature with attribute and value
  - coordinates stored separately
  - R stores everything in the same file but with subdivisions
  - For ex. ESRI has 5 files for a .shp-file

Raster data (ascii-format)

ncols 2001
nrows 2001
xllcorner 1599975
yllcorner 7199975
cellsize 50
NODATA_value -9999

461 462 463 463 461 458 454 450 446 445 445 445 445 445 445 443 442 442
441 440 439 438 437 436 435 434 434 433 432 430 428 427 426 423 422 422
422 420 419 419 419 419 419 419 419 419 419 419 419 419 419 419 419 419
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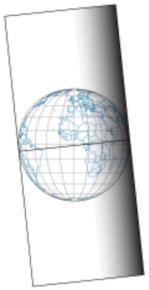
471 475 481 489 496 503 509 515 520 525 530 535 543 549 555 559 561 562
563 565 568 569 570 570 569 565 558 549 536 522 509 498 489 482 476 474
472 466 459

Vector to raster or vice versa

- Possible and sometimes necessary for analysis
- Loose information about the attributes - only one value per cell in a raster

- Raster to vector possible
- At small scale possible to do manually
  - For example a stakeholder interpreting a satellite image may draw polygons representing different features

Spatial reference systems



- Geographic coordinate system
  - Degrees, minutes, seconds
  - Decimal degrees
- Projections - projected coordinate system
- Transverse Mercator (TM) normal for Sweden/Europe
- World Geodetic System 1984 used in GPSes - WGS84

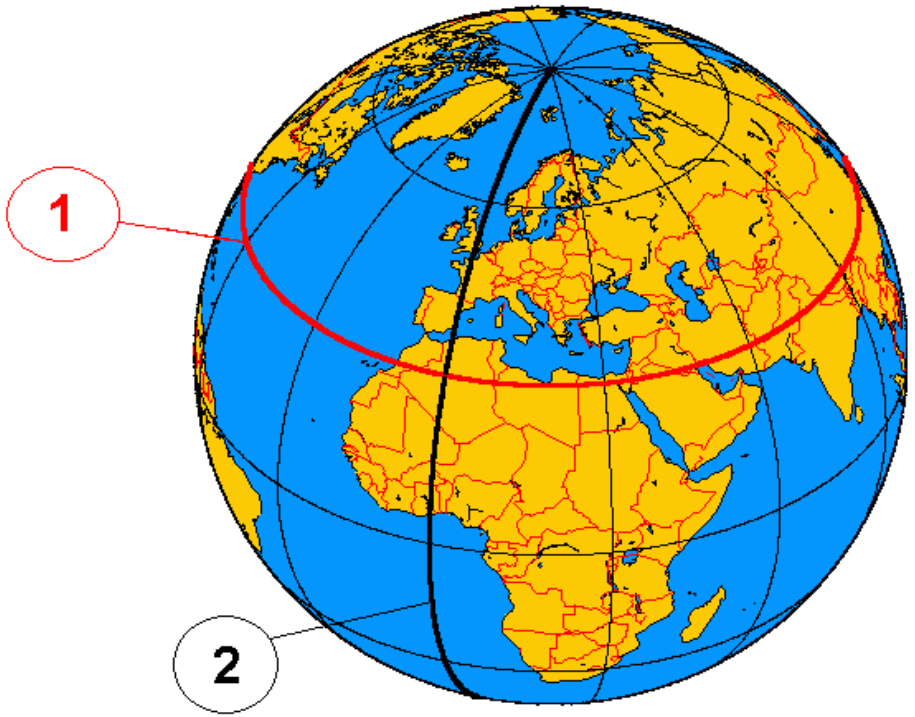
Longitude and Latitude

Latitude = 1

(0° = Equator) the angle distance from the equator

Longitude = 2

(Prime meridian) Greenwich



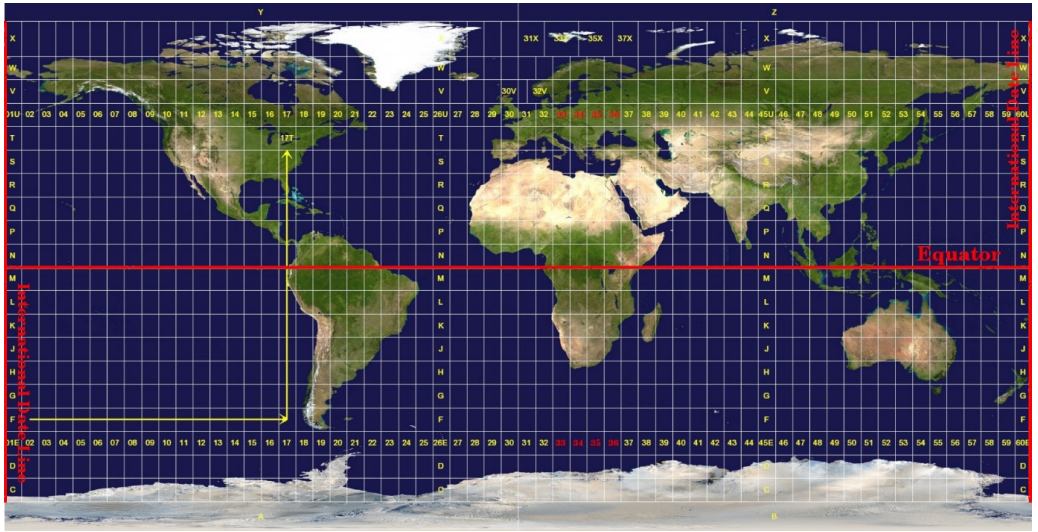
European Petroleum Survey Group (EPSG)

- http://spatialreference.org/
- For example
- WGS84 -> ESPG:4326
- Sweref99 -> ESPG: 3006
- and old system RT90 -> ESPG: 3021

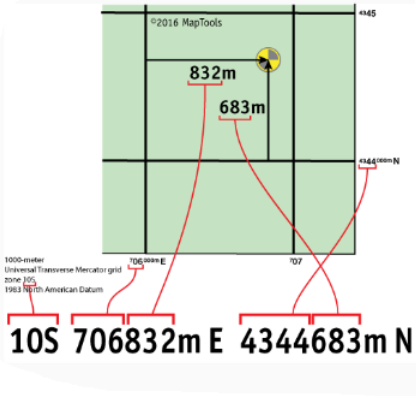
Spatial reference system

- Geographic
  - Degrees, minutes, seconds
  - Decimal degrees

- Projected (meters)
  - Universal Transversa de Mercator (UTM)



Zone and coordinates
- X UTM: 706832 m E
- Y UTM: 4344683 m N
- Zone: 10S



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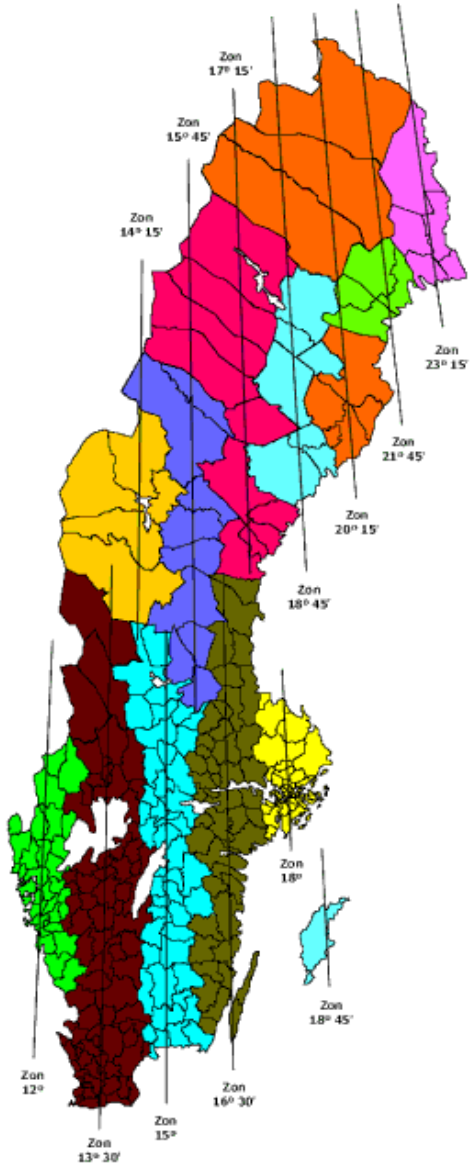
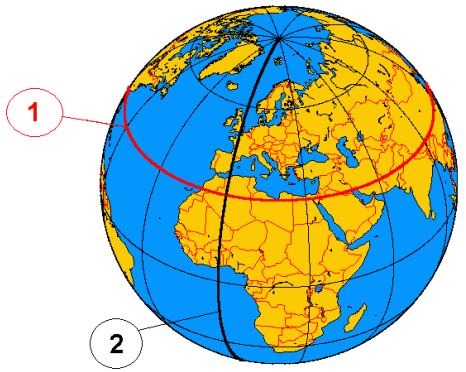
QGIS 3.16 User Guide

In Sweden

- **RT90** (special case in R!!)
- Since 2007 **Sweref99 TM** – based on UTM zone 33N.
- If we would use only UTM we would have to divide the country in three parts.





	Latitude/Northing	Longitude/Easting
Lat/Long	N 63° 31.1714'	E 16° 55.4388'
RT90	7046151	1555690
Sweref99	7044913	595707
UTM-format	7044913	595707

Long, Lat, X-coord, Y-coord…

- Remember that
  - X-coordinates in RT90 = Northing coordinate in Sweref99, i.e. the Latitude
  - Y-coordinates in RT90 = Easting coordinate in Sweref99, i.e. the Longitude
- So Y-coord=x and X-coord=y
- `coordinates(data) <-c("x", "y") # in R`

The UTM system is in meter scale

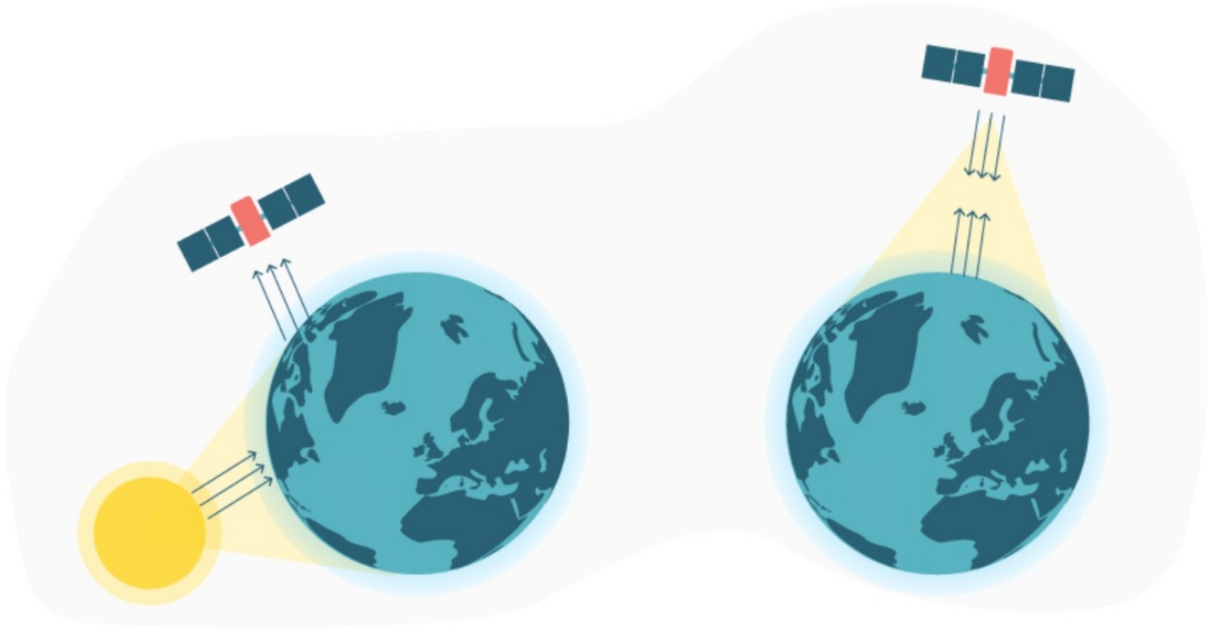
Remove one figure and decrease the accuracy

- 588010 7495048 - 1 m
- 58801 749505 - 10 m
- 5880 74950 - 100 m
- 588 7495 - 1 km

Temporal reference system

- For time the standard reference system is Coordinated Universal Time (UTC) – atomic time.
- Greenwich Mean Time (GMT) is a time zone – mean sun time at the meridian (Greenwich). (<1 sec)
- GMT or UTC never change to daylight saving.
- UTC is used in the Global Positioning System (GPS)
  - Numeric time reformat to time format using 1 January 1970 as reference.

Environmental data – Remote sensing



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Edusat

Environmental data – Remote sensing

Satellites:

- Landsat (1-9)
- Sentinel (1-5)
- MODIS

Satellite	Sensor	Spatial resolution (pan)	Spatial resolution (multi)	Spatial resolution (thermal)	Swath width	Revisiting time
IKONOS	Ikonos	0.82 m	3.2 m		11 km	1–3 days
QuickBird-2	BGIS 2000	0.61 m	2.4 m		17 km	1–3 days
WorldView-2	IRU	0.46 m	1.85 m		16 km	1–4 days
WorldView-3	IRU	0.31 m	1.24 m		13 km	5 days
SSTL-150	RapidEye		6.5m		77 km	5.5 days
Landsat 1–3	MSS		80 m		185 km	16 days
Landsat 4 & 5	TM		30 m	120 m	185 km	16 days
Landsat 7	ETM+	15 m	30 m	120 m	185 km	16 days
Landsat 8	OLI/TIRS	15 m	30 m	100 m	185 km	16 days
SPOT 1–4	HRV, HRVIR	10 m	20 m		60 km	2–3 days
SPOT 5	HRG, HRS	5 m	10–20 m		60 m	2–3 days
SPOT 4 & 5	VEGETATION		1,000 m		2250 km	1 day
Terra	ASTER		15–30 m	90 m	60 km	1–2 days
Sentinel-2	MSI		10–60 m		290 km	5 days
Terra/Aqua	MODIS		250–1,000 m	1,000 m	2,330 km	1–2 days
NOAA 6–18	AVHRR 2-3		1,090 m	1,090 m	2,000 km	1 day

ICT Sensor and Satellite Database

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Environmental data – Where?

Vector data

- OpenStreetMap Data Extracts: OpenStreetMap data
- Ecoregions: data on ecoregions and biomes of the world
- GADM: limits of administrative areas in the world
- Natural Earth: diverse limits
- Protected Planet: protected areas
- UN Biodiversity Lab: Several data bases for the world
- HydroSHEDS: hydrological information for the world
- Global Roads Inventory Project (GRIP): roads across the world

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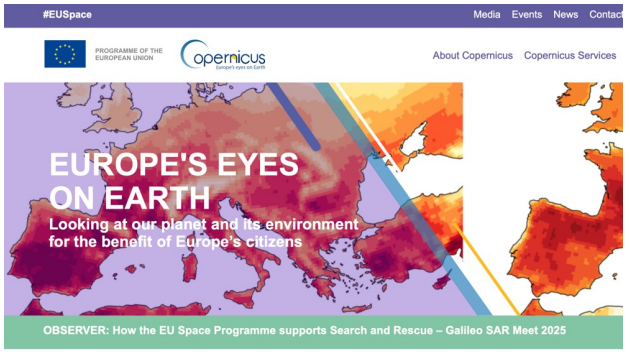
Environmental data – Where?

Raster data

- USGS: open data for several satellites
- SRTM: elevation data
- Global Forest Watch: land use and land cover change
- Copernicus: multiple products derived from satellite and remote sensing
- Geoservice Maps: elevation and forests
- GlobCover: land use and land cover for the globe
- Global Human Footprint: human footprint data
- Land-Use Harmonization (LUH2): current and predicted land use across the planet
- SoilGrids: soil data
- WorldClim: bioclimatic data
- CHELSA: climate data
- EarthEnv: land cover, clouds, relief, and hydrography
- MARSPEC: ocean conditions and variables
- Bio-ORACLE: ocean conditions and variables



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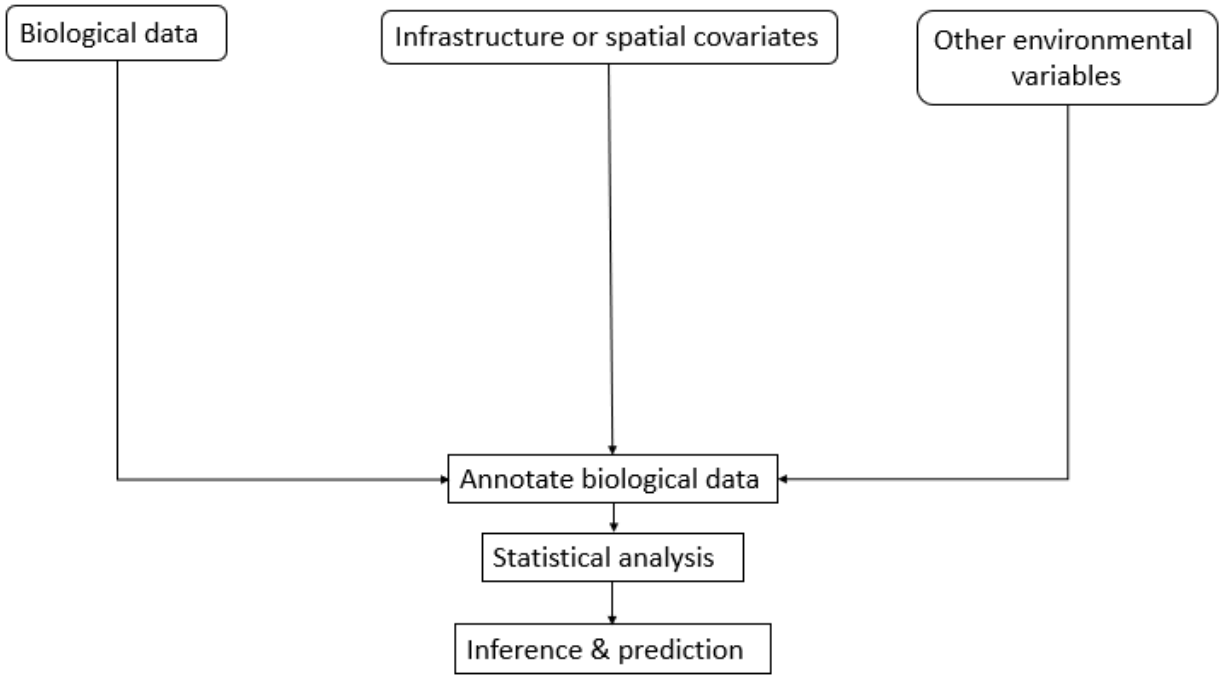
Environmental data in R

R packages

- rnaturalearth: data from the world map from Natural Earth
- rworldmap: global data maps
- spData: datasets for spatial analysis
- OpenStreetMap: access to open raster images of streets
- osmdata: download and import OpenStreetMap data
- elevatr: access elevation data from various APIs
- rgee: use Google Earth Engine through R
- copernicus: access and process COPERNICUS Global Land Vegetation products
- oneimpact: tools to compute zones of influence of infrastructure

Data annotation

- Data annotation consists of enriching a data set with other information that provide context to it.



Data annotation

- Data annotation consists of enriching a data set with other information that provide context to it.

```
terra::extract()
amt::extract_covariates()
amt::extract_covariates_along()
amt::extract_covariates_var_time()
```